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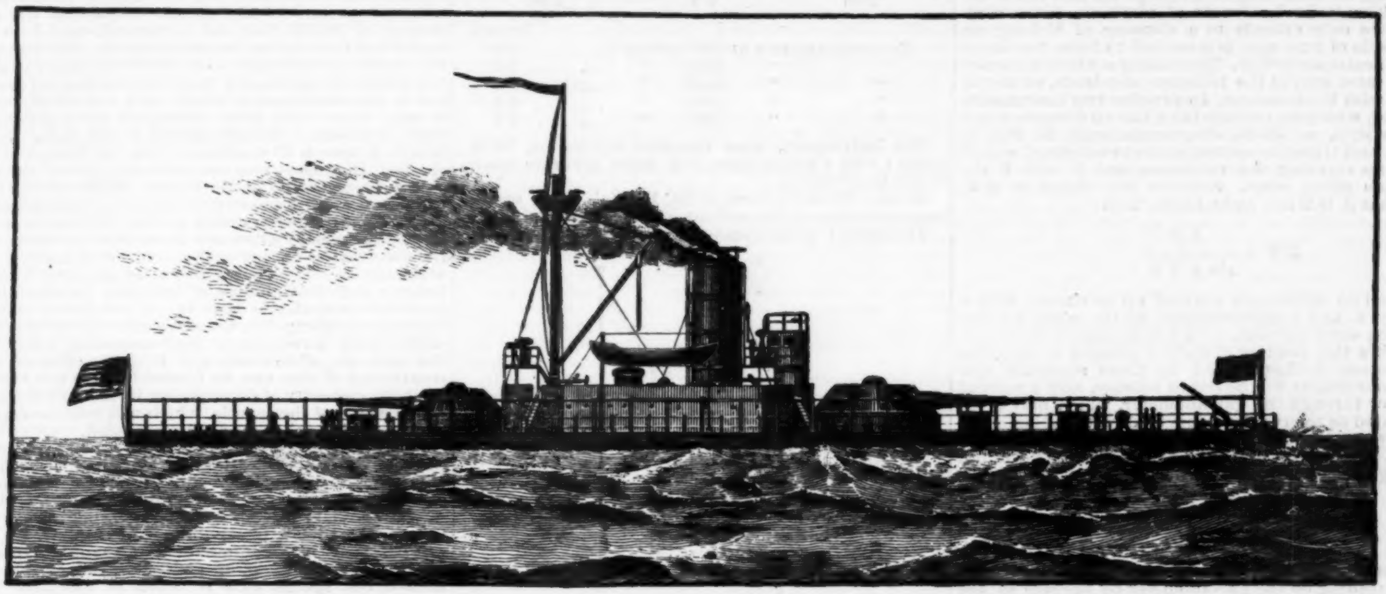
THE MONTEREY.

We give an engraving of the new double-turreted, twin-screw, armored coast defense vessel Monterey, launched the first week in May last from the yard of the Iron Works, San Francisco, in the presence of President Harrison and party. Mrs. Harrison touched the electric button which released the vessel from the ways. The Monterey is powerful and strong, being well equipped for coast and harbor defense.



THE NEW ARMORED COAST DEFENSE VESSEL MONTEREY.

The contract for the construction of the vessel was awarded to the Union Iron Works June 4, 1889, and she makes the third man-of-war of the new navy launched from the ways of that enterprising firm.

The general dimensions are as follows: Length over all, 261 feet; load water line, 256 feet; extreme breadth, 59 feet; mean draught, 14 feet 6 inches; displacement, 4,000 tons; displacement in fighting time, 4,486 tons; armor belt amidships, 13 inches thick; indicated horse power of engines, 5,400; estimated speed, 16 knots.

The Monterey is constructed entirely of steel and has a double bottom throughout, there being 110 water-tight compartments in her hull that can readily be filled with water, submerging the vessel until only about one foot of her sides shows above water.

The propelling engines are of the triple expansion type, 30 inches stroke, the high pressure cylinder being 27 inches, the intermediate 41 inches, and the low pressure 64 inches in diameter, which, with the vacuum, etc., are expected to develop, with steam pressure at 160 pounds per square inch and 150 revolutions per minute, 5,400 horse power. There are two main boilers, made of steel, 11 feet 2 inches in diameter, with a length of 10 feet 7 inches, with four other tubular boilers in addition, and all designed for a pressure of 160 pounds.

The armament of the vessel is to be as follows: Two 12 inch breech-loading rifled guns with 13 inch steel armor protection; shield 8 inches thick; projectile weighing 850 pounds; powder charge, 425 pounds; two 10 inch breech-loading rifles mounted en barbette, with 11½ inch steel armor protection; steel shields 7½ inches in thickness, projectile weighing 500 pounds and powder charge 250 pounds.

There are to be also 54 six-pound rapid firing rifles; four 37 millimeter Hotchkiss revolving cannon and two one-pound rapid-firing rifles. In addition to the above armament, she will have a 15 inch pneumatic dynamite gun, which will throw 1,000 pound projectiles containing 500 pounds of dynamite or other high explosives.

The Monterey is fitted with the Ward sectional boilers. Much of their merit lies in the small space they occupy, together with speedy steam generation, economic consumption of fuel and the easy manner with which repairs can be made in case of accident.

The engines, boilers, and magazines, in fact all the machinery, will be protected by armor, 16 inches in thickness, rendering their safety almost certain from the inroads of hostile projectiles.

It will be easily seen that with the completion of Cruiser No. 6, the Oregon, and the double-turreted monitor Monadnock, together with those already built and in commission, San Francisco will soon be able to turn out a fleet of war vessels well able to protect herself and the California cost.—*Min. & Sci. Press.*

FISKE'S RANGE FINDER.

It is well known that there are two main causes of inaccurate gunnery at sea, one cause being the uncertainty as to the distance of the target, the other cause being the difficulty of recognizing the exact instant when the rolling of the ship brings the gun to the proper elevation for firing.

For ascertaining the distance, it cannot be said that

Fig. 1.

Fig. 3.

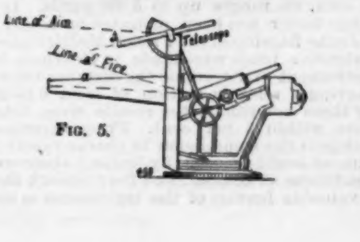


Fig. 4.

Fig. 5.

THE FISKE RANGE FINDER.

any satisfactory method exists at present, beyond that of assuming a distance and correcting the subsequent shots, by noting whether they go over or fall short; while for determining the time to fire, the gun captain, keeping the pupil of his eye on the line joining the front and rear sights, waits until this line intersects the target. The inaccuracy of this latter method lies in the fact that it is impossible for a gun captain to balance himself in a seaway, and, at the same time, to keep the pupil of his eye exactly on this line.

Lieutenant Fiske, of the United States navy, in endeavoring to overcome these two sources of error, has perfected a range finder and an elevation indicator which we describe below. The first determines the distance, and the second substitutes for the uncertain line of the gun sights the optical axis of an accurate telescope. This telescope is so secured that it does not recoil with the gun. The gun captain, therefore, can brace himself in position, and keep his eye exactly against the eye piece, and recognize with positive certainty the precise instant when the line of sight of the telescope intersects the target.

The range finder is shown in Fig. 1, and consists of a fairly powerful telescope mounted on a standard, which can be rotated round a vertical axis, corresponding with the center of the large disk shown in the engraving. One-half of the edge of this disk is graduated to 90 deg. on either side of a zero point, and below the graduation is fixed a length of platinum silver wire. This wire only extends to a distance of 81·1 deg. on either side of zero, and is intended to form two arms of a Wheatstone bridge. The sliding contact is carried by the same arm as the telescope standards, so that it moves with the telescope. In practice two instruments are used, which are mounted at a known distance apart on the ship, as shown diagrammatically in Fig. 2. Here A and B are the centers of the two disks, C and D the arms carrying the telescopes, and E and F the platinum silver wires. Suppose the object is at T, such that A B T is a right angle, then

$$A\,T = \frac{A\,B}{\sin A\,T\,B}$$

If the two sectors are coupled up as shown, with a battery, *h*, and a galvanometer, by the wires, *a b* and *c d*, then since the arm, *c*, on being aligned on the object takes the position c^1 while *d* remains at zero, the Wheatstone bridge formed by these segments and their connections will be out of balance, and a current will flow through the galvanometer, which may be so graduated as to give the range by direct reading, since the current through it will increase with the angle A T B. In general, however, the angle A B T will not be a right angle, but some other angle Φ. In this case

$$A\,T = \frac{A\,B}{\sin A\,T\,B} \times \sin A\,B\,T$$

and hence it will only be necessary to multiply the range reading on the galvanometer by the sine of the angle A B T, which can be read directly by the observer at B. This multiplication is not difficult, but by suitably arranging his electrical appliances Lieutenant Fiske has succeeded in getting rid of it, so that the reading of the galvanometer always gives the range by direct reading, no matter what the angle at B may be. To explain this, consider the two telescopes shown in Fig. 2 in the positions, C and D; the whole current then has a certain resistance. Next suppose them, still remaining parallel, in the positions C^1 and D^1. The total resistance of the circuit is now less than before, and hence if C^1, one of the telescopes, is moved out of parallel to the other, through a certain angle, the current through the galvanometer will be greater than if it were moved through an equal angle out of a parallel when the telescopes were in the positions C and D. The range indicated is, therefore, decreased, and by properly proportioning the various parts it is found that the range can always be read direct from the galvanometer, or in other words the multiplication of

$$\frac{A\,B}{\sin A\,T\,B}$$

by sin A B T is to all intents and purposes performed automatically. There is, it is true, a slight theoretical error; but by using a small storage battery and making the contents carefully it is said to be inappreciable. Each instrument is fitted with a telephone receiver and transmitter, as shown in Fig. 1, so that both observers can without difficulty decide on what point to align their telescopes. It will be seen that it is necessary that the lines of sight of two telescopes should be parallel when the galvanometer indicates no current. It has been proposed to accomplish this by sighting both telescopes on a star near the horizon, which being practically an infinite distance away insures the parallelism of the lines of sight. The range finder has been fitted on board warships belonging to the United States, French, and Italian navies, all of which have made very extensive tests of the accuracy and value of the instrument.

Although the Fiske range finder has been under the notice of the naval departments of different countries for so short a time, it has been very favorably received, the remarkable results obtained by the exhaustive trials carried out on board different United States warships having given a sufficient guarantee of the practical value of the instrument. The French government have bought the right to use it, while the Italian navy has tried it carefully.

In the American navy the range finder was installed on board the Baltimore, and from the extensive trials made with it there, during six months at sea, the writers of the official report state that it is accurate within 3 per cent. on ranges up to 5,000 yards. In France the range finder has been mounted on board Le Formidable, the flagship of the French Mediterranean fleet, and extensive trials were made in February last with the instrument to determine the distance between vessels having a relative motion of from 0 to 28 knots. Under these conditions the results were found to be accurate within 5 per cent. From experiments on fixed objects the commission in charge report that the instrument could be used by trained observers under the conditions of combat, and they remark that a specially valuable feature of the instrument is that it enables the observer to record the distance—to within a very small percentage—between forts or ships, before firing grows heavy.

Difficulty in observation would, of course, be increased in a heavy seaway, but not so much as would the accurate pointing of the guns, so that the range finder can be always relied on to give more accurate work than the guns. The commission consider the instrument will be particularly useful at night, as the mere flash of a gun will be sufficient to give the range of the vessel firing it. Even more satisfactory experiments were made on board Il Terribile, of the Italian navy, at Spezia last month, when it was found that, with the ship moving, the distance of a moving target was ascertained with an error of only 1·3 per cent. per 1,000 meters range.

The annexed table gives a short *resume* of the results obtained in these trials:

Mean Distance, Meters.	Mean Percentage of Error.	Percentage Error in 1,000 Meters.
2290	3·25	1·45
1565	1·8	1·22
1950	2·4	1·23
3240	6·8	2·10
3880	2·8	0·70
3640	4·0	1·10
2978	5·8	1·90

	Per cent.
Hence mean error at 1000 meters is........	1·3
" " 2000 "	2·6
" " 3000 "	3·9
" " 4000 "	5·2
" " 5000 "	6·5

The instruments were mounted 58·9 meters, 197 ft., apart; with a longer base, still more accurate results would be obtained.

Messrs. Elliot Brothers, of St. Martin's Lane, are the manufacturers of the instruments for Great Britain.

The second of Lieutenant Fiske's inventions is an

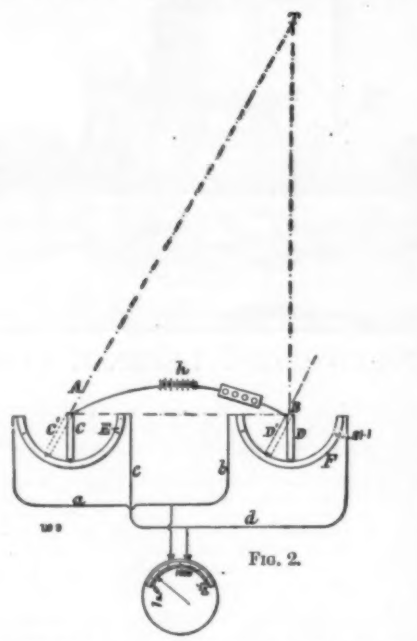


FIG. 2.

elevation indicator, also for use on shipboard, which we show in Figs. 3 and 4. It consists of a shield telescope, which can be mounted either on the shield, as shown in Fig. 5, or on the platform, or on the conning tower of the ship. In the former cases it rides on a horizontal axis parallel to the gun trunnions, moving with the gun, so that the telescope and the gun sights always point in the same direction, but by means of the graduated disk shown at the back of the instrument, the telescope can be set so as to make a greater or smaller angle with the horizontal plane than the gun does. The main difficulty in obtaining good results at sea is to fire at proper elevation, and the object of Lieutenant Fiske is to insure this. Thus suppose the range is such that an elevation of 2 deg. should be given to the gun. By Lieutenant Fiske's system the gun is trained horizontally, the elevation being given instead in an opposite direction to the telescope, which in the instance taken would be depressed 2 deg. The gun is then trained on the object and the officer in charge keeps his eye to the telescope till the line of sight is brought dead on the mark by the rolling of the ship, when he fires the gun by any suitable means. Should the water be so smooth that the vessel does not roll sufficiently to give the required elevation, part of it is given to the gun and the remainder to the telescope, and the gun fired when the line of sight is on the mark as before. Not the least of the advantages claimed for this instrument is that, by making the cross-wires incandescent by an electric current, as is done with many kinds of telescope, a night sight is produced, which is at once simple and exact. The device has been fitted experimentally on board the Yorktown with, it is stated, satisfactory results.—*Engineering.*

TESTS FOR STEEL USED IN THE MANUFACTURE OF ARTILLERY.*

By Dr. WILLIAM ANDERSON, Director-General of Ordnance Factories, Royal Arsenal, Woolwich.

THE physical and mechanical properties of steel depend upon so many conditions, that the greatest difficulty exists in devising tests which shall give the user of steel reasonable certainty as to the intrinsic qualities of his material, as well as some idea of its condition with reference to internal stresses. At first sight it would appear that chemical analysis ought to provide the most certain indication of the nature of a specimen. The purchase and manufacture of very many substances are guided by chemical tests alone, and the results are eminently satisfactory. Why should not chemistry, in its present advanced state, render equally certain indications as to the qualities of steel? The answer, I think, lies in the circumstance that the mechanical properties of steel, and of alloys generally, are affected in a remarkable manner by extremely minute quantities of substances associated with the dominant metal, by the relative proportions of these substances, by the changes in some, or in all, of them, produced by more or less rapid changes of temperature, which influence dissociation and reveal their effects by the singular phenomenon known as recalescence, which also indicates, though to a less degree, allotropic changes in some or all of the components.

Chemical analysis sufficiently minute to detect even traces of every substance associated with iron would be so tedious and costly as to be impracticable, and I fear that many years must pass away before chemical and physical science together will succeed in determining the laws which govern the mechanical properties of alloys. Some advance has already been made by Professor Roberts-Austen, who has shown that there exists a relation between the mechanical properties of some alloys and of the atomic volumes of the substances of which they are composed, and I do not doubt but that farther investigations in this direction will enable metallurgists to predict with some certainty the effects of ingredients upon the mechanical properties of the substances to which they are added, but it is only those who have attempted such systematic work as Professor Roberts-Austen is now doing for the Alloys Research Committee of the Institution of Mechanical Engineers who can have any idea of the difficulties which surround the inquiry, chiefly arising from the practical impossibility of obtaining pure materials in sufficient quantity, owing to the liability to oxidation of the metals which are most used in the arts, to the disturbance caused by the occlusion of gases, and to other causes. The time which must necessarily elapse before a sufficient number of facts can be established to enable unassailable laws to be laid down, and the corresponding expense, are sufficient to deter the most enthusiastic investigator. But assuming, even, that the laws are discovered, and that the effect of each constituent of steel can be foretold, there will still remain the necessity of determining by analysis the exact constituents of the sample, which will involve expense and loss of time that cannot be conceded.

For these reasons, and acting under the advice of the president, the specifications of gun steel used in her Majesty's service exclude all definitions of chemical composition, in so far, at any rate, as the proportions of the ordinary ingredients of steel, such as carbon, manganese, silicon, phosphorus, and sulphur, are concerned. The introduction of new material, such as chromium, aluminum, or nickel, is, indeed, not forbidden, but special care is taken to ascertain their effects upon the mechanical properties of the metal before their use is sanctioned.

With respect to steel for lighter work, such as small arms, and especially for use in the production of swords and bayonets, some restrictions in chemical composition are imposed. In the former case, however, the percentage of carbon is defined with a view to the hardening which some portions of the components of a rifle have to undergo, and with reference to the durability of the barrels in regard to erosion by powder gases and abrasion by the bullets. In the case of swords, the difficulties of framing a satisfactory specification are so great that the subject was specially referred to Sir Frederick Bramwell and to Sir Benjamin Baker, and by them the nature of the steel to be used was, indeed, defined by its chemical composition, but with the sole view to secure uniformity in supply, the sword maker being permitted to vary the components of the steel he proposed to use within certain limits.

Once, however, the quality supplied is found suitable by the mechanical tests imposed, the chemical composition so selected is not to be departed from beyond reasonable limits of toleration; and I think that I may venture to affirm that the chemical tests for sword steel were adopted only because it was found impossible to define the qualities required by physical tests alone, seeing that sword blades have to be hardened and tempered, and are, therefore, subject to internal stresses, the nature and intensity of which certainly depend upon the chemical constituents of the steel, as well as upon the form of the blade and the mode of treatment.

It is not, I think, sufficiently realized that metals, and, indeed, most substances, are incapable of appreciable cubical compression, that is, change of volume under any stress that can in practice be brought to bear on them, under whatever conditions they may be, whether fluid, in the pasty state, at forging temperature, or cold.

Like ice and water, steel and cast iron have a greater volume in the solid than in the liquid state, and, therefore, red hot solid cast iron or steel floats on the surface of the molten mass, and hence, to some extent, is due the sharpness with which the metal takes the form of the mould in casting. The molecular motion in the metal, which results from the continued application of heat, culminating in producing a change from the solid to the fluid state, although it must constantly increase in energy, does not necessarily imply a greater mean distance between the molecules; in fact, the distance often becomes less, since the liquid is often more dense than the solid; hence it is probable that the motions of the atoms in the molecule are affected, which view certain other changes due to thermal influence seem to support.

In the process of solidification the outer surface sets first and becomes rigid, but as the cooling proceeds, in spite of the slight swelling of the mass due to solidification, the loss of volume arising from cooling asserts itself, and since the outside cannot be drawn in altogether on account of its being set and comparatively cold, the inside of the mass is broken up into porous places or into hollows, so familiar in large castings of unequal thickness; and even if solution of continuity does not occur, the casting is in a condition of internal stress which a trifle may develop into rupture. As the cooling proceeds, the inside contracts, and the outside, which had set in a stretched state, becomes violently

* From a paper recently read before the Iron and Steel Institute, London.

compressed, while the inside remains in a state of tension; and if the material yields, the sudden release of the outside surface causes the parts to spring asunder with such violence that the stress, which was originally compressive, is suddenly turned into tension high enough to cause rupture with such energy as to be generally accompanied by a report.

In the case of wrought steel cooling suddenly from forging heat, similar action takes place. When annealed from below the temperature, *b*, of Chernoff, that is to say, below the temperature from which, in cooling gradually, crystallization can take place, the fall of temperature on the outside and in the inside proceeds at nearly the same rate, and the contraction is consequently uniform throughout, and no internal stresses arise; but if heated to the same point and quickly immersed in oil or water, the surface is rendered rigid in every direction, and contracts upon the heated core, and this being incompressible, the surface has no alternative but to stretch. If it does this without fracture, the mass of metal is apparently uninjured; but should the tenacity be unequal to the stress, rupture takes place at once. Should the metal survive the violence it has been subjected to, the subsequent cooling will gradually relieve the tensile stress on the surface, and substitute a compressive one in all directions, while the core will be in a state of tension also in all directions, and in some cases these stresses become so severe that a slight disturbance of temperature, or the application of mechanical force, will determine rupture with more or less noise. This has been frequently observed in hardened armor-piercing shot, in steel coining and stamping dies, and even in oil-treated gun hoops and tubes, though made of mild and tough steel; and in these the late General Kalakoutsky succeeded in accurately measuring the strains in a great number of instances, and in calculating the intensity and direction of the stresses which produced them. In consequence of the conjugate nature of the stresses, the fractures are generally of a serrated, branching and diagonal character. As there is no such thing as an absolute elastic limit, time, to some extent, obliterates the internal stresses; the metal slowly yields under them till a sort of armed neutrality is produced, so that after a few months' repose spontaneous fracture need hardly be dreaded; and for this reason dies and armor-piercing shot are kept in store for some time before being issued for service. The proper way, however, to restore neutrality, when hardness need not be retained, is to heat the steel to about the temperature, *a*, of Chernoff's scale (about 900° Fahr.), and suffer it to cool slowly. This is found to obliterate the internal stresses, while retaining, in a great measure, the so-called high elastic limit and ultimate strength, which oil-hardening undoubtedly communicates. If, however, the process of hardening has set up fissures or cracks, however minute, in the interior of the mass, and these are just as likely to be longitudinal as transverse, no subsequent annealing can repair the mischief done, and in this lies the great danger of oil-hardening. I attribute to it most of the failures which have occurred in artillery; and although all nations are in accord in practicing the oil treatment of gun steel, it is a remarkable fact that civil engineers do not feel justified in taking advantage of the undoubted increase of elastic and ultimate resistance communicated to steel by the process, on account, I presume, of the risks attending it. There is no contesting the fact that the effects above described do follow sudden changes of temperature; but the action is by no means regular, because both the allotropic and chemical changes in the material are influenced not only by changes of temperature, but also by the state of pressure or tension which such changes tend to produce, so that certain combinations of pressure and temperature may develop much more marked effects than others. This is well illustrated by the changes which take place in drawing and rolling metals and their alloys; they are rendered hard and brittle by mechanical tensions and pressures alone, and often to the same degree as by sudden cooling.

The difficulties which surround the framing of a specification for gun steel were enhanced by the circumstance that till quite lately the steelmakers did not manufacture guns, at least for her Majesty's service, while the gunmakers did not produce the steel which they required. Hence it became necessary to test the material practically in the rough-forged state, and by a process which aimed more at ascertaining what the steel was likely to do when ultimately treated in the recognized manner than to determine its properties in the particular state in which it was tested, which was consequently not the condition in which it was to be built into the gun. The specification now in force in her Majesty's service lays down that the specimens, which are to be cut from the components of the guns in a carefully specified manner, are to be 1 inch diameter by 4½ inches long; they are to be heated to 1,525° Fahr., or a bright red, and quenched in oil of 65° Fah. temperature, and left in the oil till cold. They are then to be turned down for a length of 2 inches to a diameter of 0·533 inch, and tested by tearing asunder. Bending tests on specimens 4½ inches long, and 0·75 inch wide, and 0·375 inch thick, cut to these dimensions after being oil-hardened, are also prescribed. In samples so small the probability is that the internal stresses set up by the oil treatment, even though it is not followed by annealing, are not very severe, and they are greatly relieved, in the specimens tested by tension, by turning off nearly a quarter of an inch all round the operative part. But the temperature at which the hardening is effected lies between two temperatures at which important molecular changes take place in the material. The researches of Gore, Barrett, Osmond, Professor Roberts-Austen, and others, show that at about bright red heat, or 1,500° Fahr., iron undergoes a molecular change, made manifest by the evolution of heat sufficient, if not actually to raise the temperature of the metal, at any rate to retard its rate of cooling. Such evolution of heat must be due to molecular or atomic change, which is clearly reversible. In heating a bar, the rate of absorption must be momentarily increased at the point of recalescence; in other words, the specific heat of the material is increased at a particular temperature; or rather, as a molecular change has taken place, the heat absorbed or evolved would be more correctly called latent. We have no information as to whether a change in specific gravity takes place also; but since liquid iron is more dense than solid, it seems probable that increase of density commences at the point of recalescence, and is maintained when the metal passes into the fluid state. A similar phenomenon is apparent in water, which attains its maximum density at 39° Fahr., and then commences to expand as the temperature falls, and maintains that expansion till converted into the ice into which it ultimately turns. Water colder than 39° Fah. appears to be an allotropic form of water warmer than that temperature.

The allotropic change which takes place in iron at 1,500° Fahr. is probably accompanied by a change in physical properties, producing what Osmond has called α and β irons. Apparently, when the change takes place in gradual cooling, the β iron, that of the higher temperature, and which Osmond conceives to have hard molecules, passes into the α state, in which he supposes the molecules to be soft. Cooled rapidly, in either state, soft iron results; but in the presence of carbon or of some other substances, the β iron is supposed to retain some of its hard nature, and to be the cause of hardening in steel.

In addition to this change in the iron, which forms the main component of steel, it is now demonstrated by the researches of the president, Akerman, Osmond, and others, that the carbon, at any rate of steel, exists in two conditions, namely, either in the form of a definite compound of carbon and iron dissolved in an excess of iron, or as greatly subdivided carbon diffused through the mass, and that at certain temperatures association and dissociation take place, the combined carbon becomes diffused, and the diffused carbon combines.

The act of combination being a chemical process might be expected to declare itself in the evolution of heat, and the researches of Osmond laid before this institute last year abundantly show that at about the temperature of 1,200° Fahr., or red heat, such an evolution of heat does take place.

Struck by the importance of the researches to which I have drawn your attention, and imagining that the methods pursued by Osmond opened up the possibility of arriving at a knowledge of the condition of large masses of steel with respect to their uniformity of composition and physical condition, I suggested to the Institution of Mechanical Engineers that it could not do better than institute a systematic research into this matter.

The proposal was adopted with the utmost readiness. A strong committee, of which our president is a distinguished member, was formed, and Professor Roberts-Austen was requested, adequate assistance being provided, to undertake the work. He readily accepted the task, and I venture to think that already very encouraging success has been met with. It would obviously be improper for me to explain here the means by which the work is being carried out. A report will very shortly be presented to the Institution of Mechanical Engineers. It will contain the fullest information, and I will therefore only state that Osmond's experiments have been repeated, the rate of cooling of specimens has been registered by the most ingenious automatic methods, and curves produced from which it is possible for even an inexperienced eye to detect the two points to which I have drawn your attention. The mode of procedure requires but very small samples, and a few minutes suffice to obtain a record; so that I am sanguine that before very long a method will be arrived at by which it will be possible to determine the quality and conditions of masses of steel, from the mere shavings turned off, far more accurately and rapidly than by means of any test which we are able at present to apply; and this power is of vital importance now that we propose to build up guns of immense masses of steel, the quality of which, though it may be determinable by present methods at the ends, cannot be ascertained without great loss in other parts of their length. The investigations prove, at any rate, that steel is being treated, or ill-treated, now at temperatures which lie between two critical points, separated from each other by only some 300° Fahr. It has to be treated in masses of ever-increasing magnitude, and the temperatures at which the hardening and annealing are performed can only be judged of by the eye—an extremely unsatisfactory method, considering how much the appearance of a heat is modified by the intensity of the light around. I cannot divest myself of the feeling that the apparently capricious behavior of steel is due not only to the internal stresses engendered by oil-hardening, but also to the circumstance that the chemical condition of the steel and its molecular structure are greatly influenced by comparatively slight errors of judgment, or by carelessness in the adjustment of the temperatures at which the operations are performed.

The circumstance that within the last two or three years three important firms have undertaken the manufacture of heavy guns from steel of their own producing, and have introduced powerful forging presses, renders it possible to modify our specifications in the sense that more attention shall be paid to the nature of the steel employed, and to the mode of working it, than heretofore. It is in contemplation to provide that open-hearth steel only shall be used; that the ingots shall be treated in a special manner when hollow forgings are to be produced; that a certain minimum amount of work shall be put into the steel, and that annealing from a red heat, or about 900 deg. F., shall always be the last operation, even if the mechanical properties aimed at can be attained without hardening in oil or water. It is remarkable that foreign nations appear to attach much more importance to determining the elastic limits than is done in her Majesty's service. The French and American specifications prescribe both the elastic limit and the ultimate strength. The Russian specification defines the elastic limit only, though the ultimate elongation per cent. is prescribed. I believe that the Germans follow the same rules, though I have been unable to obtain any direct information on this point. In her Majesty's service a limit of permanent extension under a load of 21 tons per square inch is prescribed, and a note is to be taken of any yielding under a less load; but the term "elastic limit" is carefully excluded, on the ground that no such limit can, in fact, be defined. All foreign nations seem to prescribe hardening in oil, though no mention is made of any particular temperatures, and in all cases the first and the last operation must be annealing, after which only the test pieces are taken. At the Abouchoff Steel Works, the hardening and annealing is practically one operation, the object to be treated being immersed in the oil only for a short period, the duration of which is a matter of judgment, and depends upon the dimensions of the steel. It is then rapidly withdrawn and returned to the heating furnace, where it is allowed to cool slowly. It is impossible, within the limits of a paper suited to these meetings, to enter into all the details of the question I have ventured to bring before you. My object is to draw attention to the recent advances in the theory of steel, and to suggest how the knowledge, even now, in our possession must gradually affect our practical work. I trust that the discussion, which will, no doubt, arise, will give to the world the knowledge and experience which is so peculiarly the dower of the members of the Iron and Steel Institute. A discussion followed.

Dr. Anderson said the observations that M. Chatelier had made confirmed those of Sir Lowthian Bell as to the volume of steel and cast iron at about the same temperature as the molten liquid being greater than the fluid mass. When the metal was cold the volume was less, no doubt, and when it got heated up to a cherry red heat, apparently it began to float, and after that the volume was decidedly greater than that of the molten mass. Of course, that had an important bearing upon the application of steel which he had drawn attention to. What he had endeavored to show in the paper was confirmed by what Mr. Hadfield remarked, that he found great difficulty in producing a shell of the required quality, that was, that he had a good many failures before he had one success. That was generally the case with steel castings, and with regard to the shell, he thought it exactly arose from that cause, that they were dealing with it at temperatures in which changes took place that depended on various circumstances. The difficulty was to hit off the temperature at which the changes were favorable to the result it was sought to obtain. He believed that the rationale or theory of the difficulty of working steel was that they were obliged to work at temperatures where these various changes took place in the chemical composition of steel, and changes connected with the allotropic form. It was over and over again said, "That bent because the steel was too soft;" but when they asked what softness meant, they were told that soft steel would stretch more than hard steel, whereas the fact was that within the elastic limit there was no difference whatever in the stretching per ton between the softest steel and the hardest. Recently, Captain Younghusband made some experiments with a view of determining that very point on rods 100 inches long. Similar experiments had been made at Enfield with regard to swords, and it was found that perfectly hard steel, as hard as it could be made, would bend. In answer to Mr. Carbutt, he would say that oil-hardening had not been given up; but there was a tendency not to insist upon it if the quality of steel could be obtained by other means. Annealing had in all cases been adopted as a final operation, and was insisted upon. The difficulty was that all nations had adopted it, and it was hard to imagine that they would have done so, and have stuck to a process which had not some virtue in it. He himself had always been greatly against it, thinking that the danger was greater than the advantage. He would, at the same time, say that, to a certain extent, his paper ought not to have been produced. When the president asked him to prepare it, he thought a new specification for steel would have been published and become a service specification; but for some reason it had not yet been adopted into the service, and it was a rule that such things were not to be made public. Therefore his hands were tied, but he had done his best. The tendency was to test the steel in the condition in which it would be tested when put into the gun. In cases where the steelmaker was also the gunmaker he would, of course, have the whole thing under his control, and might produce the steel in any way he liked, provided the last operation was annealing, and it passed the examination after being cut from the steel in the mass. That was a direction in the specification, and he hoped very soon it would be promulgated. He did not quite catch the meaning of Mr. Head's question. Steel that cracked spontaneously usually opened out. At any rate, the parts could not be joined together again. The stress was evident, and made a displacement of parts which prevented their ever being joined together again; but in some recent experiments made at the gun factories by cutting off slices of hoops that had been oil-hardened, it was found that they closed or opened, he forgot which; but after they were annealed to about 900 deg. F. they were neutral, so that if they were cut through they neither closed nor opened. The conclusion, therefore, was that the annealing had removed any mischief, provided there had been no solution of continuity anywhere. He was not able to answer Mr. Weston Smith's question about vibration. As far as he knew, specimens taken from guns which had been in use for some time showed no difference from the samples of steel from which the gun was made. He did not think that the small amount of use that a gun got comparatively was sufficient to make any difference in the physical state of the steel. He was very glad of the opportunity of tendering his thanks personally to M. Chatelier, who had done them the honor of coming among them now, because he really believed that the difficulty which Mr. Snelus had pointed out of finding out whether the great masses of steel now used, 30 feet long, for instance, were the same in bulk as at the two ends would be solved by M. Chatelier's pyrometer. If they took specimens all along the length of a large forging, and found that the curves were all alike, they might be pretty sure that the steel was just the same all through from end to end, and that there was no great difference caused by liquation. It should be remembered that this could be done by means of M. Chatelier's apparatus in a few minutes. If he remembered rightly, Mr. Roberts-Austen told him it took him about twenty minutes to make an experiment, whereas the preparation of microscopical specimens would take a very long time indeed. He was quite sure the president would bear him out when he said he had most profound respect for chemical analysis. It had its proper value. In the government departments they were always governed by the chemical analysis of steel, but what he meant in the paper was that they could not be sure that the analyst would search for everything in the steel, and that they were quite safe in what they were using.

[Continued from SUPPLEMENT, No. 804, page 12846.]

HARBORS, NATURAL AND ARTIFICIAL.*

By F. H. CHEESEWRIGHT.

PLYMOUTH.

PLYMOUTH Breakwater is isolated in the middle of the Sound, having half a mile of channel on either side of it. It runs direct east and west for 1,000 yards, and then at the wings deflects north at an angle of 120 degrees. The wings are each 350 yards long. It stands 5 feet above the level of the highest spring tide, and has a base of 120 yards. The average height is 14 feet; total length, 1,700 yards; and cost about £1,700,000. The cost of maintenance is £5,000 a year.

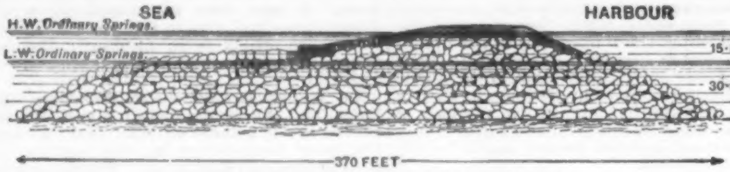


FIG. 8.—PLYMOUTH BREAKWATER.

PORTLAND.

Portland Breakwater is of a double character, consisting of an outer and inner structure. The inner breakwater is 1,700 feet in length, the outer 6,400 feet. This is another instance of the tumble stone foundation and concrete superstructure. It was begun in 1847, yet the slopes do not appear to have become properly consolidated, for they suffer continually between high and low water levels. During a single gale, 3,000 tons of stone have been known to be displaced.

ALDERNEY.

This harbor is protected by a rubble mound and a superstructure founded below water. Depth of water from 21 feet to 34 feet at outer end. The harbor works were commenced in 1847, modified in 1849, again in 1856, and afterward in 1858. The western breakwater only was carried out to a length of 4,380 feet. The actual cost up to the period of completion in 1864 was £285 per lineal foot. Cost of repairs of breaches, from 1873 to 1883, £52,850. Depth, extreme, 133 feet.

This breakwater was constructed strongly in its upper and monolithic works; the large masonry blocks forming the outer wall being tied or doweled together with huge bolts of gun metal, while the rubble and dry masonry base is continually wearing away (see cause of failure at Wick and Arklow).

To a select committee of the House of Commons, session 1872, on the harbor and fortifications of Alderney, Sir Andrew Clarke, R.E., reported that the cost of Alderney had been £300,000 less than that of Plymouth Breakwater, which was being maintained at a cost of £5,000 or £6,000 a year, and he did not think that Alderney was likely to cost more.

DOVER.

It has been proposed from time to time during the last fifty years to build a breakwater and make a harbor of refuge at Dover, but this is still in abeyance, from the immense difficulties and the extreme cost of building a suitable structure in deep water, as proposed, partly from the want of suitable material in the neighborhood, but mainly from the great cost of preparing foundations for a suitable superstructure, and the known difficulties attending them.

In the spring of 1845 the Admiralty applied to Messrs. Cubitt, Dennison, Rendel, Rennie, Veitch, Vignolles, and Walker, to make a report, plans, and estimates for enlarging and improving Dover Harbor, upon the extended scale of 500 acres, as proposed by the Commission in 1844.

As the general plan and extent had been determined by the Admiralty, the difference in the plans proposed by the last mentioned engineers consisted in the position and mode of forming the entrance and executing the works. The estimates varied from £1,100,000 to £5,000,000. The latter sum, if ever the work is carried out to the extent proposed, will probably be the cost. These plans and reports were published by Parliament in 1846.

The total cost of the Admiralty Pier is stated to have been £693,077. A sum of £22,897 has been paid in addition to the above for repairs of damage done by storm, in 1877 and following years. The whole cost has been defrayed by Parliamentary grant.

The engineers originally were Messrs. Walker & Co., afterward Messrs. McLean & Stileman, and, subsequently, Mr. Edward Druce, who had formerly acted as resident engineer under the above gentlemen.

It is a stone pier, in good condition, in a maximum depth of water of 45 feet at low water spring tide, and has no bar or shoaling at the entrance. This pier has a base of 92 feet, in order to obtain a clear roadway of 30 feet in width. The sectional area is 4,736 square feet, and the cost was £360 per foot run.

Notwithstanding the cost and care bestowed upon this work, it is said that it has shown signs of failure at the base, from causes similar to those in every case exhibited where the structure consists of either masonry or concrete blocks, laid on a loose bottom, and built or put together under water, with the assistance of divers, and without cementing, doweling, or otherwise connecting them.

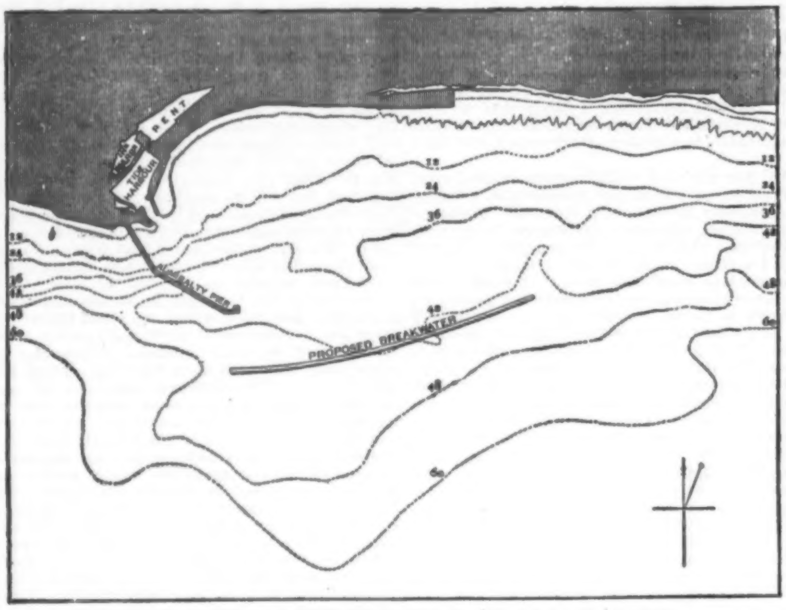


FIG. 9.—DOVER PIER AND PROPOSED BREAKWATER.

TYNEMOUTH.

At Tynemouth, we see how destructive an agency is the sea, when acting against the rubble mound form of breakwater.

The breakwaters at Tynemouth are perhaps unexampled monuments of engineering skill, neither intellect, patience, nor money having been husbanded in their production. Here, again, the superstructure is practically faultless, the weak point being the rubble mound. The superstructure is composed of concrete blocks, of a unique form, made on shore and thoroughly well aired before being lowered and set in their proper places by divers. This is, as well may be supposed, a very costly process; but it has the advantage of being successful, so far as itself is concerned. But, unfortunately, the rubble mound, although considerably more than thirty years have elapsed since it was begun, still suffers materially during the continuance of heavy gales.

This breakwater has been more than thirty-five years in the course of construction, and is not yet finished. The cost of it is enormous.

COLOMBO.

The breakwater at Colombo, which was begun in 1875, is a very fine instance of the use of Portland cement concrete. Here, again, the foundation consists of tumble stone, or *pierre perdu*, the superstructure composed of large concrete blocks, varying from 16 to 33 tons in weight. A special difficulty attending the erection of these works was that all operations had to cease during the "monsoon season," that is, from May to October. The greatest amount of work that it was possible to do upon it, in any one month, was that done in January, 1880, when it was increased by the addition of 154 feet. As the width of the wall at the base is 26 feet, and only 24 at the top, Colombo may be considered an example of an almost vertical breakwater, the greatest desideratum in all marine structures. The composition of the concrete used at Colombo was six parts of broken stone, two parts of sea sand, and one part of Portland cement.

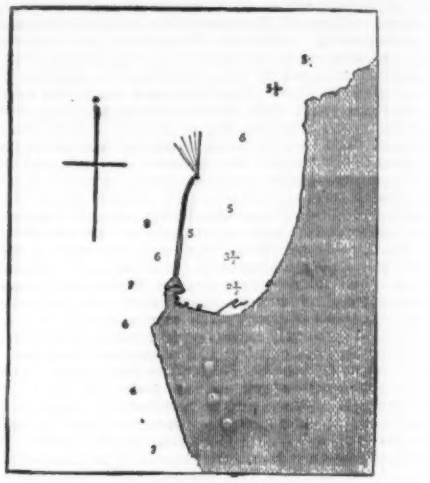


FIG. 10.—COLOMBO HARBOR.

The total length of the breakwater is 1,150 feet and its depth is 40 feet. The average cost was £170 per lineal foot.

CHERBOURG.

It was for a long period a favorite project of the French government to establish a great maritime port in this quarter of the kingdom, in order to counterbalance in some measure the great naval station at Portsmouth, situated on the opposite side of the channel, and the whole coast had been frequently surveyed and examined by the most celebrated engineers for that purpose, and reports and schemes were prepared and devised.

In 1769, however, the celebrated mole or *digue* of Cherbourg commenced by erecting wooden cones filled with stones, after the designs of M. De Cessart.

The cones failed, and in 1777, M. De la Bretonniere, a distinguished naval officer, proposed a plan to construct a detached breakwater, 12,792 feet long, having three openings, viz., one in the center and one at each end. These breakwaters he proposed to make by sinking the hulls of vessels filled with stones, in order to form an incline or base for the work in the first instance (similar to the plan which had been adopted at La Rochelle, by Cardinal Richelieu, in the year 1692), and then to cover the hulls of the vessels with loose angular blocks of rubble stone, or *pierre perdu*, so as to form one continued breakwater.

He proposed this plan of commencing the work, because he was fearful that the undercurrents and waves during storms were so strong that it would be impossible for the rubble to lie without some expedient of the kind, to bind it together in the first instance.

The objections made to the plan of M. De la Bretonniere were, first, that it would require a greater number of vessels than France could furnish in ten years; secondly, that there would be a great difficulty in get-

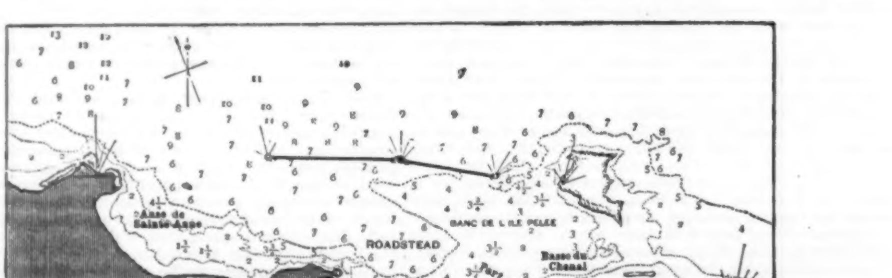


FIG. 11.—CHERBOURG BREAKWATER.

*A paper recently read before the Society of Arts, London.

ting a sufficient number of workmen; thirdly, that although the plan had succeeded very well at La Rochelle, where there were only 5 to 6 feet at low water, at Cherbourg they had 40 feet, and in some places more; and as the moles at La Rochelle were attached to the shore, the difficulties there were comparatively trifling to those that would have to be encountered at Cherbourg, where each length of breakwater would be isolated; fourthly, that the upper part of the breakwater would be so much exposed that it would not withstand the shock of the waves; fifthly, that it would not be high enough to give sufficient protection to the shipping within.

The authorities then adopted the plan of dropping a mass of loose rubble into the water, to find its own slope for the base, and *beton* and masonry for the superstructure, which system was carried on with considerable variations until it was finished in 1853, the total cost amounting to £2,600,000, and nearly eighty-six years were spent in its construction.

It will be readily seen, from an inspection of the various plans of harbors, that the breakwater at Cherbourg is one of the largest marine works ever undertaken, and that it has not been exceeded, as regards the extent of area sheltered, by any more recent works.

Alexandria breakwater approached it in length, and the matchless jetties at Galveston and Charleston are longer; but, considering the solid nature of the work, the batteries it supports, and the period of its construction, it remains a monument of engineering skill and perseverance.

It does not, however, equal in depth, or in section, several other breakwaters, but it furnishes a perfect type of a breakwater formed on a rubble mound with a superstructure founded at low water.

HOLYHEAD.

The breakwater at Holyhead is another example of the rubble base foundation, with a superstructure of masonry in large blocks, set in lime, and springing from low water level on the harbor side of the mound.

The breakwater has an average depth of 40 feet, and extends into the sea to a maximum depth of 55 feet. It was begun in 1849, and finished in 1873, costing £1,285,000. The total amount of stone used in the construction of this great work has been estimated at 7,000,000 tons. The cost was about £163 10s. per lineal foot.

With the exception of a place at the extremity of the breakwater, it has stood remarkably well, and has cost but an insignificant sum for repairs; but at the end the mound is not quite stable, and tends to travel round the head. Various methods have been adopted to check this tendency, and finally the curious plan was hit upon of placing old chains, weighing 1,000 tons, in coils along the foreshore; this effectually kept the foreshore from shifting, and at the same time offered no solid face for the action of the waves. This end has suffered considerably at various times, repairs to it still going on, to make good recent damage.

WICK.

In Scotland, Wick is one of the most notable examples of a rubble base with block superstructure. This has been one of the most unfortunate erections of modern times, gale after gale having played havoc with it. In 1868 the outer portion of the structure was seriously damaged in some places, the rubble base being washed down to about 15 feet below low water.

In 1869 the damage had been repaired, and the work reconstructed in cement, when in 1870, during another storm, 380 feet of it was seriously damaged, and again, in 1872, further mischief was done.

ABERDEEN.

The breakwater at Aberdeen was begun in 1870, and finished in three years; its length is 1,050 feet, and is 35 feet wide at the head of the roadway.

The following is a good description of this breakwater, and the injuries it has received.

The landward end, for 500 feet in length toward the sea, had been covered with a thin layer of stones and sand. Of course the sand was cleared away in order to secure a solid foundation before the works were proceeded with. The manner in which the natural inequalities of the foundation were overcome was by leveling up with a deposit of concrete in small bags, on which blocks of Portland cement were built without being cemented.

These blocks, weighing from 10 to 20 tons, were carried up to a uniform level of 4 feet 9 inches above low water spring tides, except at the seaward end, where they were terminated at 9 inches above low water of spring tides. The blocks are composed of 1 measure of Portland cement, 4 measures of pit sand, and 5 measures of stones. The concrete superstructure, 18 feet in height, was built over the blocks in frames *in situ*, a large number of blocks being incorporated with it. The superstructure is composed of 1 measure of Portland cement, 3 measures of pit sand, and 5 measures of stone or shingle. An apron of concrete, deposited in bags, lies at the bottom, along a part of the sea or eastern side of the foundation. It commences about 600 feet from the shore, or about 100 feet from the rock foundation, is then carried round the head of the breakwater, and returned along the breakwater, wooden piles being driven 18 feet apart. Each pile is 2 feet in diameter, and passes through the whole depth of the work.

The piles are stepped into iron shoes at the foundation, and, where they pass through the substructure, are surrounded by blocks, moulded to the form of the piles, the junction of the blocks being formed at the middle of the pile. The upper foundation courses of blocks have sustained damage along the whole length of the breakwater on the sea face, and along a part of the harbor face. The holes excavated in the upper courses have hitherto been repaired at low water spring tides, by filling them up with small bags of concrete, and finishing the surface with a facing of Portland cement mortar. These patches have stood well, with the exception of the repairs at a point 500 feet from the commencement of the breakwater. The breach at this point was further repaired during the summer of last year. These repairs, however, again gave way in the winter of 1890; and the breach was enlarged by successive storms from the northeast to dimensions noted in reports of 6th February, 10th March, and 18th May. The survey made on the 6th February showed the hole to be 22 feet in length, or 3 feet into the breakwater. The survey of the 10th March showed an increase to 72 feet in length, by a depth varying from 4 to 12 feet, with part of the inner row of blocks removed; and on the 18th May this breach formed a cavern 90 feet in length, 12 feet deep, and 23 feet into the breakwater. On examination of the breach by divers the foundation of small bags of concrete, on which the blocks rested, was found to be removed from under the blocks at each end of the breach.

The superstructure was also damaged on the sea face, close to the lighthouse tower, a breach being formed 54 feet long by 23 feet deep, and about 4 feet into the breakwater. At a point on the sea face, 100 feet landward from the tower, another breach was made extending partly into the base of the structure and the upper course of blocks. The blocks composing the substructure are chipped and abraded on the sea face, especially near the level of low water. The piles, where they pass through the superstructure, have been eaten away by the sea worm (*Limnoria terebrans*), leaving spaces 2 feet diameter between the blocks. The cost of the repairs was estimated at £17,000.

DELAWARE BAY.

In the year 1828, a commission appointed by the American government recommended the construction of a breakwater in Delaware Bay. The work was required, from the fact that from New York Harbor to the mouth of Chesapeake Bay, there was no good place of shelter along the coast for vessels exposed to easterly gales. The entrance to Delaware Bay, on the south side, was judged the most advantageous point for constructing a harbor of refuge, though open to the most dangerous gales from the Atlantic, and those across the water of Delaware Bay, from the northeast by the north, round to the west. The place is also exposed to the fields of ice that are brought down by the ebb tide during the winter. The plan of the breakwater was consequently designed to guard against dangers from these different directions. It consisted first of a straight mole, 1,203 yards long, in five to six fathoms of water, the sea slopes being curved after the form assumed by the breakwater at Cherbourg. The work was commenced in 1829, under the direction of Mr. Strickland; and in 1834 it was so far advanced that vessels found protection behind it. The stone used in this work was obtained from a variety of sources; some trap rock from the Palisades on the Hudson River; greenstones, from the northern part of Delaware; and gneiss, from different quarries in the same State. These rocks, though averaging a weight of 175 lb. to the cubic foot, were insufficient to withstand the action of the sea in the course of the construction of the moles. During the winter season, those upon the surface of the work were more or less displaced, and a large block seven tons weight was moved 18 feet to the inner slope of the ice breaker, down which it was lost. At the same time, about 200 tons of other heavy stone, which had been thoroughly wedged and compacted together, was torn up, and swept over to the inner side. In the United States, there have also been constructed breakwaters of considerable magnitude upon the great Northern lakes, for the protection of harbors, as at Buffalo.

RELATIVE ECONOMIC VALUES OF DIFFERENT DESIGNS FOR BREAKWATERS.

I have collected the following cost of different breakwaters from the minutes of the Institution of Civil Engineers and other sources:

Name of Breakwater.	Depth of Water (in Fathoms) at Low Water.	Cost per Lineal Yard, Pounds Sterling	Remarks.
Joliette, Marseilles	5 to 6	225	No rubble.
Algiers	6 " 10⅝	366	All large.
Holyhead	3 " 9	480	Beton.
Marseilles	5 " 9	328	Blocks.
Portland	8 " 10	348 to 360	Convicts.
Alderney	3 " 22	705	Labor.
Dover	1 " 7	1,080	
Plymouth	6·6 " 7·5	600	

Having thus briefly reviewed some of the most notable of breakwaters forming harbors, it is now my duty to call your attention to the invention of John Lewthwaite, which claims to overcome most of the defects that have been found to exist in the methods that I have brought before your notice.

Theoretically, it overcomes every difficulty that has hitherto stood in the way of the construction of effective breakwaters or sea walls.

Its real value can, of course, only be tested by experience, which very shortly we shall have—putting it to a practical test—as it is already adopted for some large works on the west coast, which will be begun as soon as the necessary capital for the construction has been raised.

The main difficulties hitherto experienced may be summed up in:

1. Faulty foundations.
2. Absence of vertical line for sea front.
3. Want of continuity.
4. Great length of time required for construction.
5. Enormous cost.

We have seen that the tumble stone foundations have serious disadvantages; (1) they require a great number of years to consolidate; (2) they cover a great extent of sea bottom, and are, consequently, liable to encroach upon the seaway into the harbor; and (3) they assist the waves in destroying their own superstructure.

In elucidation of the last remark (3), it should be stated that scientific men are now all agreed that waves act with less energy upon a vertical than upon sloping wall. In the case of the vertical wall, the wave acts only by means of its statical pressure, but when hurled upon a long slope it gains a great amount of progressive motion, and, consequently, great percussive force. The result is that the whole weight of the water multiplied by the rate at which it is traveling, would be the measure of its force exerted upon the wall erected at or near the termination of the slope.

The second difficulty, absence of vertical line, has to a certain extent been dealt with already. It is now universally admitted that the great desideratum in breakwaters is the vertical wall, rising direct from the sea bottom. This has been nearly attained at Dover, Colombo, and elsewhere with beneficial results; at Dover and Tynemouth, at an enormous outlay of time and money, since all the course beneath low water has had to be set by divers, a system of working than which no more expensive one has yet been invented.

As regards the third difficulty, want of continuity, it may, without exaggeration, be fairly said that there is not one single artificial breakwater the whole world round which possesses this very important quality; a study of the plans will bear this out. Even Portland, that may be described as one of the finest in the world, suffers from the defect, for we have seen that sometimes in one gale as much as 3,000 tons of it have been swept away. Various methods have been adopted to add continually, as much as possible, to the component parts of a breakwater. At Alderney and

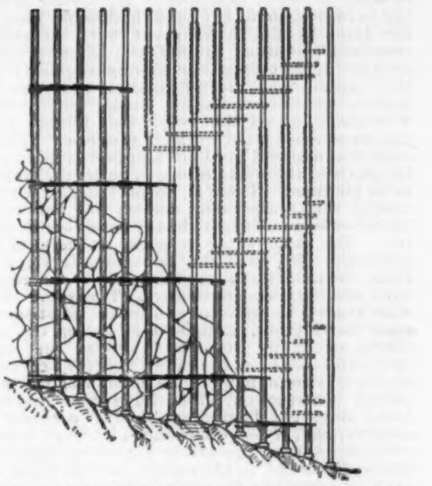


FIG. 12.—OPEN WORK SYSTEM FIXED ON UNEVEN ROCKY BOTTOM.

Wick we have found that huge bolts of gun metal and iron were employed for binding together the large blocks of masonry, but all the ingenuity displayed has not yet succeeded in producing a really continuous and satisfactory work, and failure in a greater or less degree has been the result.

Coming to the fourth difficulty—great length of time required for construction—Cherbourg is an example of the enormous lapse of time required, under the talus system, to produce a breakwater approaching effectiveness or perfection. In other cases, where a fair amount of efficiency has been obtained in a comparatively short space of time, it has been at a proportionately high expenditure of money.

This brings us to the final difficulty in the way of breakwater construction—its enormous cost. A breakwater erected under any of the present recognized systems of construction, taking say twenty years to construct, might cost the sum of £2,000 to £5,000 a year to maintain it in repair.

In order to overcome the difficulties that have been enumerated during the course of this paper, Mr. John Lewthwaite invented the system which is shown in the models before you. This system is known as "John Lewthwaite's Patent Cable Breakwater;" and I think you will agree with me that a very fair (I shall not say perfect, as time alone will prove that) attempt has been made to overcome the difficulties which have hitherto baffled the skill and ingenuity of the most accomplished engineers. In Mr. Lewthwaite's system, the nature of the sea bottom is no bar to the successful erection of a breakwater of any magnitude. Let

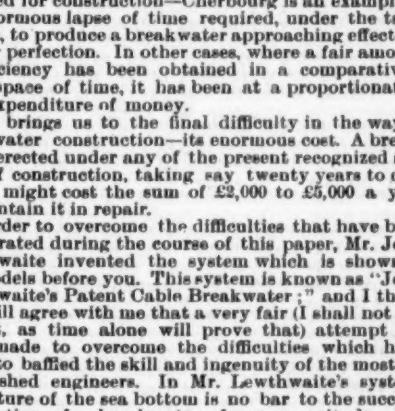


FIG. 13.—METHOD OF ADAPTING THE CONCRETE BLOCKS TO UNEVEN ROCKY BOTTOM.

the bottom be uneven or rocky, let it be even of clay, sand, or mud, the construction will be in no way retarded or hindered. As to supplying that most desired of all things in breakwater and sea building, vertical wall, a very short inspection of the models will satisfy the most captious that such a result is attained. As regards perfect continuity, and making the structure one whole, the way in which these models show the ties which bind the front and back walls together will speak for themselves. A breakwater constructed on this plan becomes, in fact, a monolith.

It is calculated that the time taken to erect a work upon this system will prove the shortest on record;

and, moreover, as once the necessary material is at hand, the greatest rapidity can be used in running out the work. The engineers in charge can select their own time for active operations, collecting during rough weather a large amount of all the necessary materials, which can be put together so soon as there is a prospect of a few weeks' continuing fine weather. By way of giving some idea of the rapidity with which works on the Lewthwaite system could be carried out, it may be stated that breakwaters of equal magnitude to those at Cherbourg and Plymouth could be started and finished in two or three years. And as very little skilled labor is required, and the system can adapt itself to whatever materials lie at hand, its cost may be reckoned at about one-tenth that of any other system.

Having now gone over the subject of my paper in a way that I hope has been satisfactory, I feel constrained to finish here, although I have been obliged to leave out many examples of the science of engineering in respect to harbor construction for want of time. Sir John Rennie, in his great work on harbor construction, published in 1854, and already referred to, does not neglect to advise marine engineers that, "if they cannot find the information they need in any written treatise on marine works, their best course would be to travel the world, visit foreign parts, and gain experience from works in progress." This would seem reasonable if Sir John had been able to point out the parts of the world in which better information was to be obtained. There is no part of the world where marine works are being carried out that can add to the knowledge which is already possessed in this country. The same thing is going on here as in other countries. We have the same tumble stone foundations, the same methods of masonry or concrete blocks, with masonry superstructure. The same difficulties with regard to want of continuity of structure, the same moving silt, shingle, and *debris*, the same obstacles attending attempts to utilize the mouths of rivers and estuaries, the same frightful expense, labor, and delays accompanying all acknowledged systems of harbor construction, which have been known at all times since the beginning, have all occurred in this country, and, if not with shame, let us at least admit, with regret, that the severe strictures, openly insinuated, or inferred, in the reports of the royal commissions appointed by the government of this country from time to time, within the last fifty years, are not altogether undeserved.

THE PROGRESS OF THE ART OF MINING.*

By Prof. C. LE NEVE FOSTER.

GENTLEMEN: In taking my place for the first time as your professor, a crowd of recollections come into my mind. My memory carries me back a third of a century, and I see myself sitting under Hofmann, Huxley, Percy, Ramsay, Smyth, Stokes and Willis, little dreaming that I should ever be honored by succeeding to the chair of mining. I feel it an honor, indeed a very great honor, to have been chosen to carry on the good work of my venerated teacher, Sir Warington Smyth, who gave me my first lessons in the art which will form the subject of my course of lectures. But the sentiment of pride is mingled with feelings of the deepest regret, for I know that I can no longer look upon the face of my old friend, no longer hear his cheery voice, no longer indulge in those familiar chats about mines at home and abroad, and so gather some of the rich fruits of his ripe experience. Sir Warington Smyth was well qualified for the post he filled for nearly forty years. Scientific blood ran strong in his veins, and he was blest with a good constitution and a strong frame capable of supporting great fatigue. Indeed, his physical powers were envied by men very much his juniors. An anecdote related to me not long ago will tell you how much he impressed miners. One of the mines which he had to inspect was divided into two parts, each approaching 400 yards in depth, and his usual course was to devote two days to his task. Upon one occasion he had climbed up by the ladders from the first part of the mine, and the agent, his companion, was congratulating himself that he would soon enjoy a well earned rest when Sir Warington (then Mr.) Smyth proposed that they should descend again and do the second part. The agent, a much younger man, was ashamed to confess that he, accustomed to the treadmill work of ladder climbing every day of his life, felt much too tired to proceed, and regretfully acceded to the proposition; but, as he himself told me, he never forgot the fatigue of the double journey.

Sir Warington's mental powers were equally marked; he had a great capacity for work, as well as the power of doing it at odd times and in odd places, which is not granted to all. The monuments of his labors which he has left behind make us regret that the exigences of his official appointments prevented him from writing more. His book on "Coal Mining" is in the hands of every student of the subject, and the report of the royal commission upon accidents in mines is a proof of the ungrudging manner in which he toiled for the public weal. Out of 217 meetings of the commission in London and the different colliery districts, Sir Warington missed only four.

Calm in demeanor, not carried away by clamor, but possessing a judicial mind ready to sift and weigh the evidence brought before him, he was eminently fitted to act as chairman of the commission, and his practical experience of the subjects dealt with naturally gave him much influence among his colleagues. I can testify from my own knowledge that he was universally beloved and revered by mine agents, who enjoyed his visits to their mines as an opportunity of exchanging ideas with a master of their art.

Though I have mixed a good deal with persons who were meeting him in business or general intercourse, I never on any occasion heard an unkind word said or bitter thought expressed against him. This is what can be asserted of few public men, and happy is he who, when quitting this world, leaves behind him such a record of kind-heartedness as Sir Warington Smyth, to whom I own myself very deeply indebted, and whose memory I shall always cherish as that of a benefactor.

When seeking for a subject for an introductory address, it occurred to me that the most suitable would be a review of the progress of the art of mining since the establishment of the School of Mines in 1851; but when I came to think the matter over, I found that full justice could not be done to the theme without the resources of a better library than I possess in the country, and the expenditure of more time than remained at my disposal. I was loath, however, to give up an idea which seemed so appropriate for the occasion; and I have therefore gathered together some facts which I think may interest you as students, and with which it is desirable that you should be acquainted, at the same time pleading as an excuse for their incompleteness the reasons I have just given.

I propose to pass in review very rapidly: (1) The changes that have taken place in the production of minerals in various parts of the globe during the last forty years; (2) the principal technical improvements; (3) the amelioration in the lot of the miner; (4) the foundation of our mining societies; (5) the future of mining; and lastly, some of the problems which the mining engineer should endeavor to solve.

Europe—United Kingdom.—According to the old prospectus of the School of Mines, the mineral produce of the United Kingdom represented an annual value of 28 millions sterling in 1851; in 1889 it was over 73 millions. The principal difference in Great Britain's mineral output is the enormous increase in the production of coal. The production has gone up from 64,661,401 tons in 1854 (the first year for which I have statistics)* to 176,916,724 tons in 1889.† The following table gives the figures for the four divisions of the United Kingdom:

	1854.	1889.
England	47,421,651	129,387,934
Ireland	148,750	103,201
Scotland	7,448,000	23,217,163
Wales	9,643,000	24,208,426
Total	64,661,401	176,916,724

The county of Durham ‡ produces more than 30 million tons per annum, and Yorkshire about 22 million tons; consequently the output of these two counties alone now exceeds that of the whole of England in 1854. The yield of Scotland is more than three times as great, that of England nearly three times as great, and that of Wales more than twice as great as it was 36 years ago.

The quantity of ironstone from the coal measures is diminishing, and now amounts to only 2½ million tons (1889). This diminution is more than compensated by the increase in the output of the Cleveland district, the main seam of which was only beginning to be worked on an extensive scale about the year 1850; of late years it has yielded the large amount of 5 or 6 million tons annually. The irregular deposits in the carboniferous limestone of the Whitehaven and Furness Abbey districts have responded to the call that has been made upon them for hematite, and in 1889 furnished 2,615,880 tons, against 579,924 tons in 1854.

Since 1873, the first year for which I have any figures, the Scotch raisings of oil shale, which is distilled for the production of various kinds of oil and other products, have increased from 524,095 tons to 1,986,990 tons.

In the case of copper the decrease at once attracts our attention. Great Britain is no longer a copper producing country of any note. A production of 9,310 tons of ore and precipitate worth £29,697 can be ignored by the real copper countries, such as Spain and the United States. In lead ore again the falling off is very marked, from 90,553 tons in 1854 to 48,465 tons in 1889. Cornwall, which in 1854 had an out-turn of 7,460 tons of lead ore, can no longer boast of a single lead mine, a fact which has been prominently brought to my mind when I have been asked lately by foreigners for letters of introduction to Cornish lead mines. The accidental discovery of salt near Middlesbrough, after a long period of inactivity, has been bringing forth good fruit for some years, and 1890 marks the first working of salt at Fleetwood, in Lancashire. Tin holds its own in spite of the difficulties with which the Cornishman has to contend in the shape of increased depth and the horrible legacy of crooked shafts left him by his forefathers. The threatened man lives long, and this seems to be the case with Cornwall. From time to time there is a scare; the Cornishman is told that he will have to go to the wall, because the world is going to be swamped with tin from the Malay peninsula, the islands of Banca or Billiton, Australia, or lastly from Dakota. But the pluck of the Cornishman does not desert him; a few of the poorest mines are shut up for a time, and he pays calls on the well tried ones, confident that he will not be beaten in the end altogether.

I must not dwell too long upon Cornwall, for otherwise I shall not have space for a few general remarks about Europe.

Nearly everywhere we notice an increased production of fossil fuel. This is very markedly the case in the north of France. The two departments of the Nord and the Pas-de-Calais now produce more than one-half of all the coal of France. The output of the former has risen from 1,030,000 tons in 1851 to 4,217,795 in 1887, while in the latter the increase is more marked, being from 42,000 tons to 7,119,663 tons, the coal having been followed under its thick covering of chalk and other rocks of the Cretaceous period. The total production of France in 1888 § was 22,952,000 tons of coal, and in 1853 only 5,938,000 tons.

In the case of iron we have to note the development which has been made in working the great bed of oolitic iron ore which extends from Nancy past Metz and Diedenhofen into Luxemburg. Much of it was lost in France, when the Germans annexed Lorraine after the Franco-Prussian war, but the French are making good use of the part they retain, for it furnishes more than four-fifths of the total, 2,285,648 tons of iron ore raised in 1886.‖

According to Bergrath Wandesleben,* of Metz, some 100 blast furnaces in France, Germany, and Luxemburg are dependent upon this bed, locally known as "Minette," for their supplies of ore, and in 1888 they produced 2½ millions of tons of pig iron, or 40 per cent. of the total production of Germany, Luxemburg, and France. The amount of ore still available in German Lorraine is estimated at 2,100 millions of tons, or enough to maintain the present rate of production for 750 years.

Belgium.—In the ten years 1841 to 1850, Belgium was producing coal at the rate of about 3 million tons annually. Now the output is about 20 millions.†

Germany has progressed rapidly in its coal, lead, copper, and salt mines in the period which we have under review. In 1852 the kingdom of Prussia ‡ gave only 4,899,771 tons of coal, and in 1888 over 59 million tons, a more than tenfold increase.

The mines of cupriferous shale at and near Mansfeld date back from the end of the twelfth century; but even as late as the year 1862 the output was only 61,971 tons; it has increased with rapidity, and in 1888 was no less than 469,716 tons; having increased nearly eightfold in twenty-six years.

At the great lead mine at Mechernich, in Rhenish Prussia, the progress is similar. In 1849 the yield of ore from the plumbiferous sandstone was 1,000 tons, while in 1889 it had risen to 36,474 tons. §

The value of the famous potash salts of Stassfurt was unknown forty years ago; in 1852 shafts were sunk through the beds of potash and magnesian salts to the rock salt, which was worked for a short time. The mistake was soon corrected, and the potash salts became the main object of the mining.

In Austria and Hungary the same story of progress may be told, and the petroleum of Galicia bids fair to become an important item in the mineral resources of the empire; following the Carpathians to the southeast, we come to Roumania, with its rich salt mines and oil wells.

In Greece, the reworking of the Laurium mines and the heaps of slag and mine refuse has afforded much profit.

Russia.—Russia is becoming a coal mining country, but here the development of the enormous resources of petroleum seems to me the chief mining event which I have to chronicle. Known and made use of from very early times, naphtha did not begin to be largely worked till 1879. ‖ The manufacture of kerosene had begun in 1858, but at first the progress was very slow. In 1863 the quantity of naphtha raised was only 5,400 tons, in 1872 it was 23,800 tons, and in 1889,¶ 3,306,000 tons. It had been discovered that the oil could be got by bore holes instead of wells, and the records of the huge spouting springs are astounding. The center of the oil industry occupies an area of only 4½ square miles.

Spain.—In Spain again it is not some new discovery that has astonished the mining world, but the growth, and the very rapid and sudden growth, in the output of old and well known deposits of iron and copper. The iron of the north of Spain was so renowned that the steel produced from it had become proverbial in the famous "Bilboa blade" several centuries ago; but the extensive working of the ore dates back only from the time when the Bessemer process created a demand for hematite. As late even as 1863 the Bilboa mines, or rather quarries, were producing less than 100,000 tons of ore annually, in the fiscal years 1887-88 more than 3¾ million tons.** In 1871 our total imports of iron ore were only 324,034 tons. From Spain alone we received 3,627,646 tons in 1889, just nine-tenths of our total imports of 4,031,265 tons, exclusive of the iron from pyrites.

The great deposits of copper-bearing pyrites in the province of Huelva were worked in Roman if not in pre-Roman times; nevertheless the output continued small until recent years, when British enterprise completely changed the aspect of affairs. Spain in 1888 produced 3,202,416 †† tons of copper ore, of which by far the greater part came from the province of Huelva.

The output of lead ore reached in 1888 to the high figure of 539,986 tons, or ten times the production of the British Isles.

Asia.—In Asia we have to note the working of coal on a large scale in the north of China, the resumption, after a long period of idleness, of gold mining in India, and the proof that it can, in some cases, be made profitable. Coal mining in India is not unimportant, for the yield of the British provinces was nearly two million tons in 1889.

Tin mining, or rather the working of alluvial deposits, has flourished in the islands of Banca and Billiton and on the Malay peninsula.

Borneo has not taken that place in the mining world which it appears to merit.

Plumbago mining in Ceylon has progressed. What the output was in 1850 I do not know; but ten years before that date it was only 50 tons per annum. In 1888 it was 11,163 tons, and in some years it has been as high as 13,950 tons.

In the future we may obtain valuable results from the ruby mines of Burma and its petroleum deposits.

Africa.—"Ex Africa semper aliquid novi." This was the saying centuries ago, and it still holds good. It need hardly be said that I refer to the diamond fields. For sixteen years after the foundation of our school, the wealth lying concealed in what now constitutes the Kimberley district was unsuspected; and even in 1867 it was a lucky chance that revealed it.

The story ‡‡ is perhaps known to many present; but as it has affected in no slight degree the progress of an

* Introductory lecture to the mining students, delivered at the Royal College of Science, London, January 19, 1891, by C. Le Neve Foster, Professor of Mining and one of Her Majesty's Inspectors of Mines.

* Memoirs of the Geological Survey of Great Britain, Mining Records. Mineral Statistics of the United Kingdom of Great Britain and Ireland for 1853 and 1854. By Robert Hunt, F.R.S., page 78.

† Mineral Statistics of the United Kingdom for the year 1889, page 5.

‡ *Ibid.*, page 17.

§ Paul Habets, "Les Accidents dans les Mines et l'Exposition Generale Allemande pour la Protection contre les Accidents (Berlin, 1889)." *Revue Universelle des Mines*, 3e serie, t. ix. et xi., 34e annee, 1890.

‖ *Statistique de l'Industrie Minerale de la France pour l'Annee* 1886, p. 44. Paris, 1888.

* Wandesleben, "Das Vorkommen der oolithischen Eisenerze (Minette) in Lothringen, Luxemburg und dem oestlichen Frankreich." Der iv. Allgemeine Deutsche Bergmannstag in Halle (Saale). Festbericht, p. 317.

† Paul Habets, *op. cit.*, p. 12.

‡ *Ibid.*, p. 18.

§ *Mining Journal*, vol. lix., 1889, p. 532.

‖ "The Oil Wells of Baku." By F. Vasilieff. Proc. Inst. C. E., vol. lxxxiii., p. 405.

¶ Report for the year 1889 on the Trade of the Consular District of Batoum. Foreign Office. Diplomatic and Consular Report, No. 677. London, 1890, p. 7.

** Comision ejecutiva de Estadistica Minera. Datos estadisticos correspondientes al ano economico de 1887-88 y a los anos naturales de 1887 y 1888. Madrid, 1890, p. 7.

†† *Ibid.*, p. 326.

‡‡ Official Handbook of the Colonial and Indian Exhibition, Cape of Good Hope. T. Reunert, "Diamond Mining at the Cape," History, Productions, and Resources of the Cape of Good Hope. Cape Town, 1886, page 178.

entire continent, it will bear being repeated. A trader named John O'Reilly, who was resting his oxen at a farm, happened to notice a special stone among a lot of pretty pebbles from the Orange River upon the boer's table. He asked the boer for it, and was told he could have it, as it belonged to a Bushman boy. The stone proved upon examination to be a true diamond worth 500*l*. For two years, however, the search for diamonds was not successful, or but little successful; at last in 1869 came the finding of the "Star of South Africa," and soon there was a rush to the district.

The banks of the Vaal River were found to be diamond bearing, and in 1870 the dry diggings, in contradistinction to the wet river diggings, were first made known. But even then any one who had predicted the state of things which now exists would have been regarded as a visionary or a madman. The diggers themselves had no faith in the continuance of the deposits in depth, and geologists, who had no precedents to go by, were quite as much at a loss as the colonists. These did what was best in such a case, they followed the diamonds as long as any were to be found, and it is a matter of congratulation not only for the miners, but also for the world at large, that there are no signs of the deposits giving out in depth. I say advisedly for the world at large, and especially for the miner. I regard the discovery of the diamond deposits as the starting point of the prosperity of British Africa. Before the diamonds were well known, the average Englishman looked upon the Cape of Good Hope as a country which produced an inferior sherry, and he troubled his head very little about it. Now all this is changed. Diamonds have brought the possessions into notice, large fortunes have been made, and part of the money thus earned has been devoted to the exploration of fresh regions, apparently with the best results.

One advantage to the mining world is that the possession of ample means has enabled the great DeBeer's company, the proud owners of mines which perhaps exceed in value any other of our colonial mineral undertakings, to issue to their shareholders a report which may well be studied as a model by other mining companies. It contains a full technical account of the mode of occurrence of the diamonds, and of the method of working the deposits, and with ample explanatory drawings. If other companies would but follow this good example the art of mining would derive an immense benefit, and I should be glad if the directors of mines would ask their managers to furnish such details. If a mine manager has nothing to be ashamed of, he should not take exception to such a request. Objection on the part of a manager to give these details would suggest to my mind that he feared the criticisms of competent engineers. It was justly said in an article that I read in *The Engineering and Mining Journal** some time ago that: "Secrecy in official management, with regard to the receipts and expenditures of other people's money, almost always begets extravagance, and generally ends in dishonesty."

The "aliquid novi," which so truly applies in the case of diamond deposits of a kind hitherto unknown to science, is also borne out in the curious beds of auriferous conglomerate, which have made Johannesburg so famous. This discovery is of the most recent date, for no work of importance was done till 1887; but even in that year the yield of the Witwatersrand goldfield was 22,121 oz.; it rose in 1889 to 380,358 oz. Probably, in last year, in spite of the depression, it was nearly 500.000 oz. The value of the gold produced from May, 1887, to the end of June, 1890, was 3,323,240*l*.

America—United States.—Few, if any, countries have advanced by such rapid strides in their mining industries as the United States. Taking them in alphabetical order:

Coal.—In 1860 the total output was 15,173,000 tons. In 1870, 29,342,580 tons, or nearly twice as much, and in 1889 it reached the enormous figure of 132,419,342 tons,† about nine times as much as it was some thirty years ago.

Turning to copper the increase is still more striking, owing first of all to the great mines of Lake Superior, and secondly to the later discoveries in Montana. In the year 1852 only 1,000 tons of copper were produced in the United States. Last year‡ the Lake Superior mines yielded 44,451 tons; Montana, 51,883 tons; Arizona, 15,946 tons; making up, with copper from other States, a total production from domestic ores of no less than 121,650 tons, or very nearly one-half of the total supply of the world.

Gold.—Though the yield of gold by mines and open workings in the United States is only half of what it was in 1852, when it reached the enormous value of $65,000,000, we find that this country has taken the lead as a gold producer for many years. In 1889, however, it was just beaten by Australasia,§ when the British colonies gave a total 49,784 kilos. against 49,353 kilos. by the United States. Speaking roughly, the United States produce rather more than a quarter of the world's output of gold. California‖ heads the list with 628,875 oz., next come Colorado and Montana, each curiously enough producing the same quantity, viz., 169,312 oz.

Nevada yields 145,125 oz., and Dakota 140,287 oz. No other State reaches 100,000 oz., though Idaho comes very near it with 96,750 oz. In 1852 the output was almost entirely from California.

Iron.—Remarkable activity characterizes the development of the iron trade. In 1852 only 541.000 net tons of pig iron were made, but rapid progress was made, for in 1860 the production was 919,770 tons. In the next thirteen years it was trebled, for in 1873 we find 2,868,278 tons; in 1882, 5,178,122; and in 1890, 10,260,000 tons (net); or, to use the words of the writer in the *Engineering and Mining Journal*,¶ "the production has increased ten-fold in thirty years, has nearly quadrupled in seventeen years, and has doubled in eight years." Speaking roughly, one-half of last year's output resulted from the smelting of ores from the Lake Superior mines,** which vie with those of Spain in productiveness.

Lead.—For a long series of years Europe had no reason to fear any competition from the American lead

* Vol. xliii., 1887, page 379.
† *Eng. and Min. Jour.* vol. xlix., p. 660.
‡ *Ibid.*, vol. li., 1891, p. 6.
§ Report of the Directors of the United States Mint, 1890, p. 189.
‖ *Ibid.*, p. 84.
¶ Vol. li., 1891, p. 3.
** *Ibid.*, p. 26.

mines, for the United States were unable to supply themselves with as much of this metal as they required. Unluckily for us, but perhaps luckily for the world at large, new discoveries of rich argentiferous lead ores were made, especially in Utah, Nevada, and Colorado, which enabled the Americans, aided by a heavy protective tariff, to produce from domestic sources no less than 181,000 tons of metal last year." *

Petroleum.—It seems strange to look back to the days before the introduction of this convenient illuminant. I recollect the time as a child when candles used to be bought in of an evening with the silver snuffers upon a tray. How different now-a-days, when the poorest cottager has a light which as much exceeds the tallow candle in brilliancy as the electric light does gas. It is true that petroleum was known and used before 1859, the year in which I left the School of Mines; but that is the date which marks the beginning of the oil trade in the United States. The number of barrels raised in 1880 amounted to 27,346,018.

Natural Gas.—We had scarcely done wondering at the resources of the United States as regards petroleum, when we were startled to hear that natural gas existed in such large quantities that it could be used in Pennsylvania for industrial and domestic purposes. Natural gas was first used as a fuel in Pennsylvania in 1874, though the Chinese had as usual forestalled the rest of the world in this as in some other discoveries. The supplies of this cheap and convenient fuel are not inexhaustible, and already accounts reach us of the scarcity of the gas and the resumption of work with coal in some places.

Phosphate of Lime.—The phosphate of lime of South Carolina was recognized in 1860; but six or seven years elapsed before it was put to any practical use. The bed lies so shallow that the trade has developed very quickly, and the output for 1890 is estimated at 564,000 tons,† the proximity to the sea rendering the export very easy. The imports into this country alone in 1889 were 122,554 tons, of the value of £273,046.

Silver.—While a student at Freiberg in 1859 and 1860, I remember that reports used to reach my American comrades of rich discoveries of silver in Nevada and Arizona. I believe that the first rich silver ore on the Comstock was found at that time. At all events two of the great companies that worked that remarkable lode were not incorporated until that year. The famous mine yielded in 1876 gold and silver of the value of $38,573,984 (gold $18,002,078, and silver $20,570,078). It is true that the production has greatly diminished since then, but other mines have made up for this deficiency, and the United States stand at the top of the list in the world's production of silver,‡ with an output of 1,555,486 kilos., beating even Mexico in spite of its proverbial richness.

Before concluding my remarks upon the United States, I must express my admiration of their journalistic enterprise. I refer to the "Annual Statistical Number" of the *Engineering and Mining Journal*, of New York, dated January 3, which reached me two days ago, giving very complete mineral statistics of their great continent. Knowing from actual experience the labor entailed in collecting and preparing such statistics, I can form some estimate of the difficulties that had to be overcome; and when a private firm accomplishes a task which no government in Europe has ever thought possible, viz., the publication of its mineral statistics within three days after the completion of a year, the meed of praise should be full and unstinted.

In our own Dominion of Canada we may mention a great development of the coal trade both in Nova Scotia and in the mines on the Pacific coast. The amount of gold raised in British Columbia has decreased, not because the supplies of the precious metal are exhausted, but because the deep alluvial beds and the quartz veins require the expenditure of capital beyond the means of individual miners. Sudbury, on the line of the Canadian Pacific Railway, threatens to flood the world with nickel if this metal is required in larger quantities.

In South America mention must be made of the great "El Callao" mine in Venezuela, discovered about the year 1867, at one time exceedingly productive, and yielding gold at the rate of 180.000 oz. a year. Gold had been rediscovered in 1849 by Dr. Plassard in the very district which Sir Walter Raleigh heard of from the Indians, and which he failed to reach. The modes of occurrence of the precious metal described to him by the natives agree exactly with the reality, and in my opinion the Caratal, or Nueva Providencia, district of Venezuela is the "Eldorado" of the sixteenth century.

In my student days Chili was looked upon as a great copper country, and one of the chief competitors of Cornwall in the production of that metal; of late years copper has occupied only the second place in the mineral statistics on account of the large exports of nitrate of soda. The beds of "caliche" were known as long ago as 1821, and began to be worked ten years afterward (*L'Industrie Miniere au Chili*, by W. Lastarria, Paris, 1890). Nevertheless, it was not until the year 1880, when Chili became possessed of the province of Tarapaca, that the nitrate industry assumed the vast proportions which now characterize it. In 1880 the exports amounted to 226,090 tons; in 1888 they were 784,249 tons, and in 1889 probably over 800,000 tons. As a by-product in the manufacture of the refined nitrate, 1,665 tons of iodine were obtained from the mother liquors, and exported in the period 1880 to 1888. The working of borate of lime did not begin till 1874, and in the fourteen years 1874 to 1888 inclusive, the exports have been 16,691 tons of this mineral and 7,793 tons of borax, which have been prepared from it. Manganese mining is yet a new industry in Chili, for it dates back only five years. The exports in these five years have been 102,399 tons.

The great Huanchaca mines in Bolivia must not be overlooked. The company now working them did not commence operations till 1873, and in the eleven years, 1877 to 1888, they produced silver worth ten millions sterling, of which four millions have been profit.

Such then are some of the most noteworthy points in the history of mining in South America during the last forty years, and I must now turn to our great colonial possessions in the southern hemisphere, Australasia.

In 1851, or just about the time the School of Mines

* *Eng. and Min. Jour.*, vol. li., 1891, p. 8.
† *Ibid.*, p. 48.
‡ Annual Report of the Director of the United States Mint, 1890, p. 189.

was founded, the existence of gold was first made publicly and widely known. The professors thoughtfully issued a small handbook concerning the methods of recognizing it and working it. When all the plant required consisted in a pick, shovel, and pan, with a good pair of arms, the output rose rapidly in the colony of Victoria, and in the year 1856 as much as 3,053,744 oz. were raised, while in 1851 the production had been only 212,899 oz. It remained above 2,000,000 oz. until 1863, and above 1,000,000 oz. until 1876. At present the yearly yield of Victoria is a little over 600,000 oz. The period under review has, therefore, seen the rise, culmination, and wane of the gold production of what was once pre-eminently the golden colony.

The total yield of the colony of Victoria from 1851 to 1889 inclusive amounts to the enormous sum of 56,282,094 oz., valued at £225,128,056.

New South Wales is our great coal colony. The existence of this mineral was known from the first, and gave the colony its name. Coal was worked on a small scale even before 1829, and the output rose gradually to about 70,000 tons per annum in 1850 and 1852. Now the mines are yielding over 3 millions of tons a year. The exact figures for 1889 are 3,655,632 tons, and the increase seems very steady. The total output from 1858 to 1889 inclusive has been 45,335,012 tons, worth £21,917,764.

The tin fields of New South Wales were not opened till 1872, but since that date tin and tin ore to the value of £8,925,543 have been sent away from the colony, mainly from alluvial deposits, and now we are shown specimens from huge stanniferous dikes which intersect the granite.

The latest find in the colony has been silver. According to the official statement issued by the Broken Hill Proprietary Company, the silver was found by mistake, for the claims were staked out for tin by a shepherd, who was struck by rugged black rocks projecting from 20 ft. to 40 ft. above the general surface of the ground. This was in the month of September, 1883; and when we read the statement of accounts presented to the fortunate shareholders, we are fairly dumfounded by the phenomenal success which has crowned the efforts of those in charge. From the commencement of work at the mine up to November 30, 1890, 480,547 tons of ore have been raised, which have yielded 84,407 tons of lead, containing 20,694,324 oz. of silver, of a gross value of £4,799,874, of which £2,200,000 have been paid to the shareholders in dividends and £592,000 as bonuses. I am informed that at the present time the output of the company averages something like 200,000 oz. of silver per week, and from 900 to 1,000 tons of lead. The magnitude of these mining and smelting operations can only be appreciated by comparison with some well known district. I have, therefore, calculated out corresponding figures for the Royal Smelting Works, at Freiberg, in Saxony.

In 1889 these works produced 65,719 tons of metallic lead, or 1,263 tons per week, and 2,614,700 oz. of silver, or about 50,000 oz. a week. The total value of all the products sold from the Freiberg works in the year 1889, including gold, silver, bismuth, copper sulphate, nickel speiss, zinc, pig lead, manufactured lead, sulphuric acid, green vitriol, arsenic, and arsenical compounds, was £761,722, while the value of the lead and silver produced by the Broken Hill Proprietary Company for the six months ended May 31, 1890, is estimated at £916,542.

I can make the comparison in another way. The total value of all the minerals produced in 1889 by the mines under my inspection in nine counties of Wales, Shropshire, and the Isle of Man, was £729,949, and the total value of the output of all the mines in Cornwall* in 1889 was under £700,000 (£698,390); even when the tin ore from open works, refuse water, and foreshores is included, only £756,928. In the six months ended May 31, 1890, the Broken Hill Proprietary Company produced lead and silver ore worth £872,758. The yield of this one mine for half a year considerably exceeded the values shown in the case of my district and Cornwall for the twelve months. These figures will give some idea of the importance of the mine to New South Wales and the adjacent colony of South Australia. The richness of the mines has led to the building of a railway from Adelaide to Silverton, which is now the center of an important mining district.

At the time of the Colonial Exhibition, in 1886, visitors to the Queensland Court may have noticed lumps of ferruginous sintery quartz and brown hematite from Mount Morgan Mine, said to yield 7 oz. per ton. The glowing terms in which the richness of the deposit were described seemed almost too good to be true; but the actual working results over a series of years, and the substantial dividends paid to the shareholders, prove that there is a good basis of reality in the statements.

I have before me the balance sheet for the year 1889, and it shows that 74,415 tons of raw stone were crushed and treated by chlorination, and produced 323,542 oz. of gold, equal to 4 oz. 6 dwt. 4 grs. per ton for the total amount of stone raised. The dividends are equally satisfactory. The gold was worth £1,331,484, of which £1,100,000 was paid in dividends. It is rarely that one sees 83 per cent. of the gross receipts paid over as profit to mining adventurers. This has all come from quarrying operations on the top of a hill only three or four acres in extent.

Queensland, which was not raised to the dignity of a separate colony until 1859, when I left the School of Mines, has thus become the premier gold producer of all the British possessions.

As long ago as 1845, South Australia became famous as a copper country by the great finds of this metal at Burra Burra. But the later discoveries on Yorke's Peninsula have thrown this old mine into the shade. In 1860 the owner of a sheep run, on seeing some green atacamite thrown up by the burrowing of a wombat, sank pits in search of the vein which he felt sure must exist, and lit upon the Wallaroo lode. Mr. Marcus says that the mine began to pay all expenses from the very first and that no capital was ever called up, and very soon handsome dividends were being paid to the shareholders.

Tin, also, is coming to the fore, and in the northern part of the colony there are stanniferous dikes and alluvial deposits reminding us of those of New South Wales.

* Including arsenic, arsenical pyrites, copper ore, ocher, slate, tin ore, wolfram, zinc ore, but exclusive of china clay and slate from open works.

When we consider the vast extent of Western Australia and the smallness of its population, we may be surprised that so much mining has been done. Various gold fields have been discovered within the last few years, and judging by specimens lately sent over to this country, there is no lack of rich beds of alluvial tin ore.

For many years Tasmania gave little sign of being a mining country, but about the year 1873 we received the first accounts of Mount Bischoff, and in spite of many difficulties, owing to the nature of the country, tin has been obtained in very considerable quantities ever since; the yield of gold is a proof that other riches are awaiting the advent of a mining population.

New Zealand must not be passed over without a word of comment. Its output of coal, about half a million tons annually, is increasing gradually, and the country not only supplies its own wants but also exports fuel to other parts. The gold industry, which was practically of no importance in 1857, reached its acme in 1866 with an output of 735,376 oz., while now it is little over 200,000 oz.

Technical Improvements.—Let us now cast our eyes very quickly over some of the technical improvements which have been made in the art of mining during the last forty years. It will be convenient to take the various processes in their natural order, and follow the mineral from the time of its discovery to the getting, the haulage, winding, and preparation for the market, without omitting the necessary pumping, ventilation, and lighting.

Leschot's patent for the crown of diamonds was taken out in the year 1862, although the Egyptians may have been before him in this method of boring. The original idea was to bore holes for blasting, and not to make prospecting holes; as late as 1867 this same notion prevailed. The great services of the drill have been rendered by applying the process to the preliminary work of discovery.

The cheapening of steel has been an immense boon to the miner, for it has enabled him to be supplied with lighter, more serviceable, and more lasting tools.

The introduction of machines worked by compressed air forms an important era in the history of mining. Schumann began to try his boring machines in the mines of Freiberg in 1857, and the success obtained by Sommeiller in the Mont Cenis tunnel in 1861, and the following years, began to convince most mining engineers that the conveyance of power by compressed air to machinery underground was a matter deserving their earnest attention.

In 1867, Doering took a contract in the Tincroft Mine in Cornwall, and did work there and at Dolcoath. But on my return to Cornwall, in 1873, there was not a single machine drill at work, and the successful introduction of boring machinery into this country did not take place till 1876.

Nowadays there is not a mine of any importance which does not avail itself of this more expeditious and usually more economical method of making excavations in hard ground.

In explosives the progress has been great. Gunpowder, which had been introduced into mining at Freiberg in 1613, and into England in 1670, had remained our sole mining explosive until the discovery of gun-cotton by Schoenbein, in 1846. But gun-cotton had not come into use to any extent in mines, when suddenly Nobel brought forward nitro-glycerine as a blasting material, in 1863, and I well remember his coming to Cornwall a few years later to explain the merits of the tremendously powerful oil, of which we did not then know all the dangers.

With infinite perseverance Nobel succeeded in overcoming the difficulties of producing a comparatively safe explosive from nitro-glycerine, and by the introduction of dynamite rendered a vast service to the miner. Indeed, it may be fairly said that the success of machine drills can be ascribed in no small measure to the employment of nitro-glycerine compounds. Since 1867, when dynamite was patented in England, the crop of explosives has been a large one; and it is difficult to keep *au fait* with the various compounds in "ite" which are continually being brought out.

In the processes of sinking, due notice must be taken of the ingenious method invented by Herr Kind of excavating a shaft by boring, and the improvements introduced by M. Chaudron, viz., the adoption of a cast iron instead of a wooden lining, and the now well known "moss-box" for making a stanch joint at the bottom.

As Chaudron's patent was taken out in 1855, the process falls well within our period, and I may remark that it was first brought prominently before the notice of English readers by a paper prepared by Sir Warington Smyth, after his visit to the Paris Exhibition, in 1867.

The new freezing process of Poetsch was first tried, as far as I can learn, in 1883, and since then has overcome the difficulties of sinking in running sand and other very watery strata in various parts of the world. The Haase system of forming a protecting shield of tubes of iron, patented in 1884, is also worthy of mention. Bars and frames made of steel bid fair to oust timber to a considerable extent from its position as a supporting material for mining excavations.

For removing overburden and for excavating minerals that lie at a shallow depth the miner can now avail himself of several steam navvies, and when thick beds of alluvial gravel have to be worked, recourse can be had to the hydraulic method, by which the stock of gold in the world was at one time being increased at a rapid rate. The device of making a stream of water under pressure to wash down banks of auriferous gravel was not applied in California till 1852.

Transport along underground roads has been improved and accelerated by various clever systems of rope haulage. Steel rails and steel sleepers are common, and the wagons and their wheels are made of steel of appropriate kinds.

In winding the mineral up the shafts the main improvement consists in the almost universal adoption of wire ropes made of steel; and an entirely new departure in their construction is found in the locked coil wire rope, for in this the inventor has not hesitated to free himself from the trammels of tradition, which seem to have compelled ropemakers hitherto to copy the processes best suited for hemp, though using a totally different material.

Greater speed of winding, better guides, and even mechanical banking, are additional signs of the advance made in this branch of mining. To overcome the difficulties presented by increasing depth of mines, Blanchet has erected at Epinac his well-considered pneumatic method of hoisting.

In the department of mining which has to deal with the removal of water from mine workings, I may put upon record the completion of several famous drainage tunnels (adits). For instance there is the "Ernst August Stolln" at Clausthal, begun in 1851 and completed in 1861; it is 14 miles long including its branches.

The "Rothschonberger Stolln" at Freiberg was begun in 1844. The main or trunk adit is more than 8½ miles long, and its branches are more than 16 miles long, so that the total length of this tunnel is nearly 25 miles. The work was finished in 1877.

A much older undertaking is the "Kaiser Josef II. Erbstolln," begun in 1782 and finished in 1878. It is 10¼ miles in length and carries away the water from the mines at Schemnitz, in Hungary.

The Przibram adit, also known as the Kaiser Josef Erbstolln, is 4⅞ miles from its mouth to the Stephanschacht; the branches bring the length to 13⅝ miles. It was completed in 1859, after seventy years' work.

In this country the only great undertaking of this kind has been the Halkyn Tunnel, in Flintshire, which is still in course of being driven. Though not in any way remarkable for its length, or the depth at which it unwaters the district—for the length of the main tunnel will be only about four miles, and the greatest depth not much more than 200 yards—the quantity of water discharged by it cannot fail to attract notice. In ordinary times it is estimated that 14 or 15 millions of gallons flow out of it in twenty-four hours, and after heavy rains the discharge is found to increase considerably.

With regard to pumping there seems to be a tendency to return to the compound engine, the use of which was advocated by some of the early Cornish engineers. Double-acting Rittinger pumps are praised on the Continent; and in some large enterprises, at Mansfield, for instance, are the only ones now being erected. At Mechernich, on the contrary, I found in 1888 that preference was given to engines placed below ground. The material for constructing the pumps themselves (cast iron) remains as it was in many British districts, while in less conservative quarters it is replaced by sheet iron or steel. No doubt ere long we shall see Mannesmann tubes find their way into mines for the rising mains.

The subject of ventilation is one that has received a full amount of attention from colliery engineers, and very many of the old furnaces have been replaced by mechanical ventilators of various types. For lighting mines in which inflammable gas has been found, a vast amount of ingenuity has been displayed by inventors in order to produce a really efficient safety lamp, and the introduction of the Marsaut shield must take a prominent place in the improvements which have been made. In spite of various portable electric lamps having been brought to the notice of the miner, I am not aware that any colliery is lighted by this means, although a few pit bottoms and places where there is much traffic are lighted by fixed electric lamps.

The ore miner is certainly to be congratulated upon having less ladder climbing than he had forty or even twenty years ago, but the man engine no longer meets with so much favor as it used to do. With a well-arranged shaft the safety of ascending and descending by the cage is marvelous.

If I were asked what are the two most valuable inventions in the art of preparing minerals for the market, I think I should not be doing wrong in naming the Blake rock breaker and the continuous jigger, both of which have rendered incalculable services. The coal miner now follows the lead of the metal miner and cleans some of his impure products by washing.

It is perhaps wandering a little from my text to speak of coking, although the process is carried on at mines, but I cannot refrain from mentioning a case that came under my notice last year. Improved coke ovens and condensers have enabled a mine owner to pay all the cost of mining his coal by the gas and the products obtained from it. In other words, the coke is got for nothing; at one time the coke was the only product made use of, the gases being allowed to burn to waste.

No account of the progress of mining would be complete without a few words on the subject of government interference for the benefit of the workman. At the time of the foundation of our school only eight years had elapsed since the employment of boys under ten years of age and of females below ground had been prohibited. Then came the act of 1850 for the inspection of mines (13 and 14 Vict., cap. 100). It referred solely to coal mines and contained comparatively few regulations.

After the lapse of five years another act was passed (18 and 19 Vict., cap. 108), also applying only to coal mines. It laid down seven general rules and provided for the establishment of special rules.

The act passed in 1860 (23 and 24 Vict., cap. 151) had a longer life, and work at coal mines and ironstone mines in the coal measures was regulated by it until the passing of the 1872 enactment (35 and 36 Vict., cap. 76). This act was made to apply to coal, stratified ironstone, fireclay, and shale, and at the same time a sister act was passed to include all other mines, which by a misnomer was called the "Metalliferous Mines Regulation Act" (35 and 36 Vict., cap. 77). I say a misnomer, because the largest iron mines are not included by it, viz., those in the Cleveland district, while many important mines under the so-called "Metalliferous" Act do not produce metallic ores. This act is still in force. Lastly, a statute was enacted in 1887, after the report of the Royal Commission of which Sir Warington Smyth was president, to regulate still more minutely and effectively mines of coal, stratified ironstone, shale, and fireclay. This is the first act in which the danger arising from coal dust was recognized.

In my opinion the Metalliferous Act requires amendment. I should like to see it assimilated to the Coal Act, as regards certificates for managers; because, though the ore or the stone mine may be exempt from the accidents which claim a large number of victims at one time, statistics show that the minor casualties bring up the general death rate very nearly to the figure which prevails in coal mines. It is inconsistent not to afford to the ore miner the safeguards considered necessary for the coal miner.

The amelioration in the lot of the coal miner, owing to the lessening of the number of accidents, is considerable. During the five years comprised by the 1850 act the death rate from accidents was 4·29 per 1,000 persons employed above and below ground. In the next period of five years under the third act the death rate was 3·87 per 1,000. Under the fourth act, which remained in force from 1861 till 1872, the rate of mortality from mine accidents had dropped to 3·20 per 1,000, and the same diminution in the fatalities continued under the fifth act. Taking the fifteen years from 1873 to 1887, both inclusive, the average rate was only 2·14 per 1,000, and lastly, in 1888 and 1889, we have the very favorable figures of 1·77 per 1,000. Such a steady and constant advance on the path of safety is most gratifying. All the credit for this improvement must not be claimed as the result of government inspection, though there can be no doubt that the enforcement of strict regulations has largely conduced to it; but new discoveries in the art of mining, as well as the general spread of information by the various mining institutes throughout the country, have also had much to do with the happy result which has now been attained.

Another method of judging of the progress of mining is to ascertain the number of tons of coal which have been extracted for each death by accident. Judged by this standard also we have no reason to be ashamed of our country. In other countries there has been similar but not such marked progress.

In an interesting report upon the exhibition held in Berlin in 1889 of appliances for the prevention of accidents, M. Paul Habets gives a careful summary of the progress realized in Belgium, France, Great Britain, and Prussia.* He divides his results into periods of ten years.

Death Rate from Accidents per 1,000 *Persons Employed.*

Period.	Belgium.	France.	Great Britain.	Prussia.
1851 to 1860	2·97	3·40*	4·07	4·91†
1861 " 1870	2·60	2·96	3·32	6·33
1871 " 1880	2·45	2·21	2·35	4·90
1880 " 1888	2·13	1·57	1·94	2·96

* 1853 to 1860. † 1852 to 1860.

These figures show a steady diminution in the number of accidents excepting in Germany, for in the decade 1861 to 1870 the mortality was terrible.

Mortality from accidents is not the only point requiring the earnest attention of the mine manager and the community at large; sickness due to the nature of the miner's occupation has to be studied, and as far as possible prevented. The subject is a difficult one, but we may congratulate ourselves that a mass of information is now being accumulated year after year, which, with patient unraveling, enables a very accurate comparison to be made between the healthiness of underground work and that of other trades. Dr. Ogle, in an oft-quoted report,† shows that coal mining is a calling that brings little sickness in its train. He says, "Again, if in each case we exclude accidents, it will be found that the mortality of the coal miners only slightly exceeds that of the most healthy class of men in our table, viz., the agriculturists, that is to say, the farmers, the agricultural laborers, and the gardeners."

With the Cornish miner the case is very different, for quoting again from the same report, "the mortality of the Cornish miners is more than double that of Cornish males in the aggregate." Out of 100 different occupations named by Dr. Ogle, the Cornish miner stands last on the list but four in regard to the healthiness of his calling. The figures refer to the years 1880, 1881, 1882. The inhalation of stone dust appears to be one cause of this state of things, and though machine drills worked by compressed air have the advantage of supplying better ventilation, they have the drawback of producing far more dust in a given time, as any one dressed in dark clothes may see if he stands for a few minutes by the side of a machine with which holes are being bored dry.

The high mortality of the underground workers of Cornwall is a sad blot upon British mining; but it is possible that the calculation of the vital statistics after the next census will show that an improvement is going on, owing to the lessened amount of ladder climbing and a general amelioration in the atmosphere in which the men have to work.

No matter what new improvements are introduced, some accidents will occur, and the loss or long disablement of the bread winner must bring not only sorrow but often also dire poverty to his family if he has not in some way insured himself. The British miner has dealt with this problem without waiting for government aid. In 1862 the first of the permanent relief societies was founded for Northumberland and Durham, and since that time seven similar societies have been established in other colliery districts. There is also a central association for promoting the establishment of relief societies and for generally keeping a watch over their welfare.

The total number of persons now insured in these societies is 238,892, and the amount of good that has accrued from these provident institutions is incalculable. The last moments of many a miner have been soothed by the thought that his wife and family would not be dependent upon cold charity or the poor law, and those left behind to fight the battle of life have been able to hold up their heads as pensioners, without the slur of pauperism ever resting upon them.

In Germany the Gordian knot of a great social problem has been cut by bold legislation, securing to all workmen relief during sickness, and a pension in old age. The result of this gigantic experiment will be watched by all with the greatest interest.

I have already mentioned the fact that the last forty years have witnessed the birth of numerous societies which have as their main object the discussion of problems relating to mine engineering: 1. The North of England Institute of Mining and Mechanical Engineers, which has issued thirty-seven volumes of transactions since its foundation in 1852, full of papers of much professional value. The other societies are: 2. The Mining Institute of Scotland; 3. The Chesterfield and Midland Counties Institution of Engineers; 4. The

* "Les Accidents dans les Mines et l'Exposition Generale Allemande pour la Protection contre les Accidents (Berlin, 1889)." Par Paul Habets. *Revue Universelle des Mines*, 3e *serie*, t. ix. et xi., 34e *annee*, 1890.

† Supplement to the forty-fifth annual report of the Registrar-General of births, deaths, and marriages in England. London, 1885, p. xlix.

Midland Institute of Mining, Civil, and Mechanical Engineers; 5. The North Staffordshire Institute of Mining and Mechanical Engineers; 6. The South Staffordshire and East Worcestershire Institute of Mining and Mechanical Engineers; 7. The South Wales Institution of Engineers; 8. The Mining Association and Institute of Cornwall; 9. The British Society of Mining Students. Nos. 1, 3, 4, and 6 have been united to a certain extent, and form the "Federated Institution of Mining Engineers."

In the United States we have the American Institute of Mining Engineers, the records of whose meetings are as much valued on this side of the Atlantic as in America.

Germany has its general meeting of mining men once every three years, and the fourth assembly was held at Halle in September, 1889, when 502 persons were present, including 85 ladies. The handbooks relating to the industries of the district were very complete, and the good example set in this way deserves to be imitated by those who have charge of similar meetings in this or any other country.

The year 1889 was also marked by an International Mining Congress in Paris, which was well attended. It gave engineers an opportunity of hearing valuable discussions and of making or continuing pleasant and useful friendships.

I must also say a word about our first International Mining Exhibition at the Crystal Palace last year. Though not so complete as one could have wished, it afforded a store of information to the visitor, especially in the case of our Australian colonies. As a proof of careful and economical management, it is pleasant to remark that the guarantors have already been repaid the sums they had advanced when the exhibition was started.

It is time to have done with the past. I have said enough to show that the period which has elapsed since our school was founded has been marked by great activity on all sides. The output of all important minerals has increased rapidly, new deposits have been discovered, and the miner, who is the real pioneer of civilization, has been the cause of thriving settlements being founded in almost untrodden lands, of throwing open fresh outlets for trade and commerce, and of preparing homes for our surplus population in sunnier climes.

In addition to this we must look at our own mines; notwithstanding all the saving of labor effected by machinery in every department of mining, our mining population has been doubled; work was found for more than 600,000 persons in 1889, instead of 300,000 in 1854, and they have been better protected from the dangers inherent to their occupation. To state the case briefly, coal mining is more than twice as safe as it was forty years ago. Unfortunately no statistics exist for saying whether or no the progress in ore mining in this country has been equally great.

Furthermore, the miner is better paid, better housed, and better educated and the possessor of greater social comforts; he can protect his interests by powerful trades unions, and he is represented in Parliament by men who know from practical experience what are his necessities.

I fear that for you as students I have been dwelling too much upon the past, while you are thinking of the future. You will be wondering what there is left for you to discover or to improve. It is unwise to prophesy, but a little speculation is allowable on this occasion. Though the period under consideration has been a brilliant one, it would be contrary to experience to suppose that mineral discoveries are going to cease simply because we have reached the last decade of the nineteenth century. Even at our own door so to say coal is being found, and according to the latest information one seam struck at Dover is 3 ft. 6 in. thick, and the boring is still being deepened in search of other seams.

Is it likely that we know all the wealth existing in our colonies? The great fountains of wealth in South Africa—I refer to the diamond mines—are nearly all included in a little circle of only three miles in diameter; the rich Mount Morgan Mine, in Queensland, is as insignificant in area as it is remarkable for its wealth. The "Dark Continent" has yet to be opened, for at present there are mere scratchings except at Kimberley and a few other places. Passing to another continent, the Trans-Siberian railway is sure to lead to an increase of mining in Asia, of which it may be hoped that England will have a share. Where English capital is subscribed, English engineers are sure to be wanted.

I am making these remarks on the supposition that the same ores and minerals will continue to be required by the metallurgist; but this is not necessarily the case. New discoveries in the art of extracting useful substances from the products of the earth, or new inventions in the manufacture of alloys, may increase the value of minerals that now are of little service to us, or may give importance to what we at present regard as refuse.

Instances of this kind of very recent date at once suggest themselves. The Thomas-Gilchrist process now enables excellent steel to be made from inferior pig, which in former days contained too much phosphorus to be available for steel making. The importance of this invention in the case of the "minette" bed of France, Germany, and Luxemburg cannot be overrated.

Until the Bessemer process created a demand for spiegeleisen and ferromanganese, the beds of earthy carbonate of manganese in the Cambrian rocks of Merionethshire were of no value, save at the very outcrop where converted into oxide. Though the trade is not a large one, owing to the competition with richer ores from abroad, it has made a difference to the wealth of the county. The success of the pyrites mines in Spain is in part attributable to the fact that all the constituents of the ore, viz., the sulphur, the copper, the silver, the gold, and lastly the iron, can be extracted with profit.

On the other hand a new chemical or metallurgical process may affect a mining enterprise adversely; this happened, for instance, when the Weldon process for the regeneration of binoxide manganese lessened the demand for that mineral. Luckily the manufacture of bleaching powder requires hydrochloric acid, a by-product in making soda by the Leblanc process; the old works still require pyrites, and are still buyers from the mines, while otherwise the Solvay method of producing alkali would have made a serious difference to Spain.

I allude to these matters very briefly to show that the miner cannot afford nowadays to be ignorant of the progress of chemical and metallurgical science. He must be able to appreciate the wants of his customers, and endeavor to supply them with whatever minerals they may require for the pursuit of their respective trades. It is also greatly to his advantage to be in some degree competent to realize the effect that inventions may have upon his own line of business.

This, however, is not the only reason why a miner should have a knowledge of metallurgy. Cases frequently arise in which the superintendent of a large mining enterprise has to supervise smelting works as well as the mine itself. As instances we have Rio Tinto, where part of the copper is extracted from the ore on the spot, and Broken Hill, where the lead and silver works are on a vast scale. How can the general manager properly attend to all his duties unless he has some knowledge of the processes by which the metals are extracted? It is true that men can and do pick up the knowledge after their college days; but it is far better to start on the battle of life as fully armed with knowledge as possible, than to rely upon picking up weapons in intervals of the fray. In other words, let the student, and especially the one who is meditating a foreign career, learn both mining and metallurgy, for in many cases he does not know which art will eventually be of most service to him.

It would take me too long to point out the absolute necessity of the miner being familiar with most of the other sciences taught under this roof. An entire lecture might well be devoted to the discussion of the interesting question, What is the best education for the mining engineer? Suffice it to say that the miner cannot afford to neglect any opportunities of acquiring useful knowledge, for when far removed from the resources of civilization he has often to turn his hand to a variety of trades; he has to doctor his men if no surgeon is at hand, treat his horses or mules, mend his saddles or harness, to say nothing of his own clothes, improvise appliances for repairing his machinery, and superintend the commissariat department of a small army of laborers.

In conclusion let me say a few words about the problems which the present generation of mining engineers have before them and which all of you may help to solve.

1. A lessening of the number of accidents. I have shown that good progress has been made; but we must not remain satisfied, especially if we remark that the death roll from accidents by explosions in coal mines last year was a very heavy one. A moot point is whether our great explosions are caused by fire damp or by coal dust, or by a combination of both. It is of little use trying to combat a disease until its nature has been diagnosed correctly. For years fire damp was considered the origin of all the evil. Then coal dust was admitted to have the effect of intensifying explosions, and now comes the question whether coal dust cannot originate as well as propagate them. No doubt some of you have read the letter addressed to the inspectors of mines by the Secretary of State for the Home Department, which was recently printed in the *Times*. He directs attention to experiments lately made by my colleague Mr. Hall, which prove that "blown-out shot may, in the presence of coal dust, and in the entire absence of firedamp, cause explosions of great violence, often accompanied by volumes of rushing flame, traveling considerable distances, and possibly so far as the supply of coal dust continues."

The home secretary promises a searching investigation by competent scientific men into this question, which has received much attention from Mr. Galloway and some of my colleagues, and also from the late Royal Commission upon Accidents in Mines. I trust that the result of the inquiry will be the discovery of means of preventing the great catastrophes.

But the collier is not the only miner requiring additional protection. I have long urged the strengthening of the act which regulates the mines not included by the Coal Mines Regulation Act, and I trust that few sessions will pass by before the statute book is enriched by an enactment requiring all would-be managers of ore and stone mines to obtain a certificate, showing that they are fully qualified practically and theoretically for the positions they expect to occupy.

2. An increase in the duration of life, especially among tin miners. So much progress has been made in the science of hygiene that there is a reasonable expectation that the lives of some miners might be prolonged, and that they would lose less time by sickness, if their work were carried on under more favorable conditions, which are practically attainable.

Where the manager of a mine has any influence over the mode of life above ground, such as when the men inhabit houses or barracks belonging to the mining company, he should not fail to exert it to the best of his ability, especially in foreign countries, where the science of health has not received so much attention as it has in England.

3. An increase in the social comforts of the men. A manager should not think his responsibilities at an end when the miner leaves off work. Here again I am thinking more of the miner abroad, often living in barracks, perhaps on some mountain side, than of the miner in England, who finds working men's clubs, libraries, reading rooms, and cocoa houses close to his cottage door. But both in this country and abroad mine managers can do much toward making their employes better men and better citizens by taking some thought for their recreation and instruction during their leisure hours.

4. The establishment of harmony between capital and labor. It may be Utopian to imagine that such harmony is attainable on all occasions, still it is patent to all that boards of conciliation and arbitration assist in preventing strikes and lockouts.

5. After these social questions, there are innumerable technical problems, such as the conveyance of power, and in this branch of mining electricity is daily coming more into favor, the more extended use of machinery for breaking down minerals from the parent rock, winding from deep shafts, preparation for the market at less cost, in fact there is not a single branch of mining which is not capable of some improvement.

6. Lastly, the mining engineer and the student are both nowadays perplexed by the ever-increasing flood of mining literature; it is difficult to find time to glance over all that is published, and utterly impossible, save for those who have an exceptional amount of leisure, to thoroughly digest the pages of new matter that are laid before them. A want and a serious want of the mining profession is a publication of the nature of the "Review of Reviews," which would give in a small compass the pith of the useful papers which are now scattered through our provincial and foreign periodicals, and the transactions of various mining societies. Even if such a book appeared but once a year, as a year book of mining, the editor would earn the thanks of a host of overworked mining men, who now have to wade through page after page of books in order to ascertain whether or no there is anything that concerns their particular branch of the profession. A mere list of titles of papers, with proper references to the original volumes, would be better than nothing.

I fear that I have tired you by statistics and by my somewhat prolix remarks concerning the past, which to you is ancient history, and by my confessed inability to prophesy anything definite about the future. But I think you will have gathered one thing from my first lecture, viz., that my opinion of the future is hopeful. The wants of civilization call for increasing supplies of the treasures lying beneath our feet. Mining has gone on progressing in importance ever since the day when the men of the stone age burrowed for flints in the chalk beds of Suffolk, and though the scene of the miner's labors may have shifted from one county to another, Britain has always been and I trust will always remain a mining land. By great good fortune our colonies and other possessions seem to resemble the mother country in their mineral wealth. Under these circumstances miners will be required, and I will conclude by saying that no efforts shall be wanting on my part, nor on the part of my colleague Mr. Brough, to keep up the standard of teaching of my lamented predecessor, and so make you worthy of the distinguished title of "Associates of the Royal School of Mines."

[Continued from SUPPLEMENT, No. 799, page 12769.]

THE POWER OF WATER, OR HYDRAULICS SIMPLIFIED.

By G. D. HISCOX.

WATER WHEELS.

THE undershot wheel, Fig. 28, is mostly used where small water heads are available from wing dams or

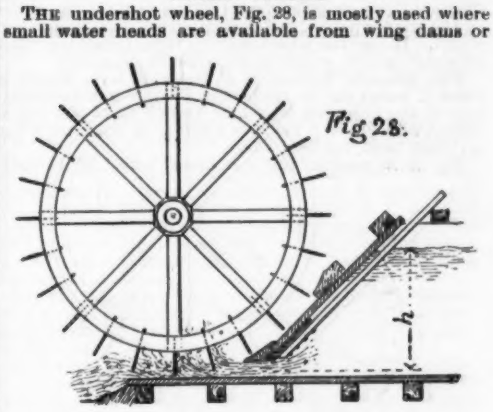


Fig 28.

races from a local rapid. In this way a head may be obtained, from one to four feet, that can be cheaply turned into power.

The flood nature of the stream should be taken into account in fixing upon the size of the wheel. If the flood rise does not exceed 3 or 4 feet, an 8 to 12 foot wheel may be used. If floods reach 6 to 10 feet, wheels should be made from 15 to 20 feet diameter—their widths according to power desired, but not much wider than their diameter.

Their best efficiency is when the speed of the periphery is about one-half that of the wheel race stream, and will vary, according to their lightness and perfection of design and construction, from 30 to 45 per cent. of the value of the water passing the gate.

As the power realized depends upon the velocity of the issuing stream from the gate, and which is variable with the variable head of water behind the gate, the formula for velocity of the stream in the wheel race will be the square root of the height of the water surface behind the gate above the center of the gate slot to wheel race, multiplied by twice gravity, or, as expressed by notation, $\sqrt{2\,g \times h}$ or $8{\cdot}02 \times \sqrt{h}$ = theoretical velocity. From the theoretical velocity thus obtained, 30 per cent. should be deducted for friction on the sole board and curb.

For example: With a head of 4 feet above the center of the opening, the computation will be $8{\cdot}02 \times \sqrt{4} = 16{\cdot}04$ velocity of the issuing stream, and 16·04 less 30 per cent. = 11·22 feet per second actual velocity.

For best effect, the periphery of the wheel should run at one-half the velocity of the stream, or in this case at 5·61 feet per second.

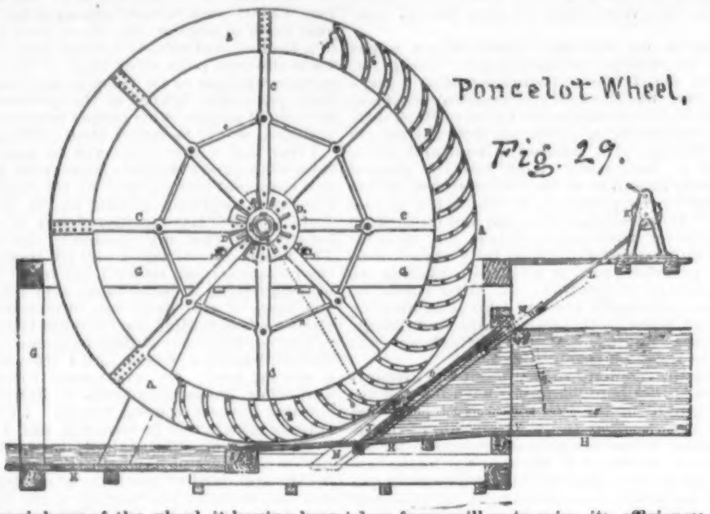
For the horse power of the stream and a wheel for the above head with a gate slot 3 inches deep by 36 inches in width, having an area of $3'' \times 36'' = \frac{108}{144}$ of a square foot, the area in square feet or decimals of a foot multiplied by the velocity in feet per second = the discharge in cubic feet per second. Therefore,

$$\frac{108'' \times 11{\cdot}22'}{144''} = 8{\cdot}41 \text{ cubic feet per second.}$$

The weight of a cubic foot of water being $62\frac{1}{2}$ pounds, then $8{\cdot}41 \times 62\frac{1}{2} = 525$ pounds of water falling 4 feet per second, and $\frac{525 \text{ lb.} \times 4'}{550} = 3{\cdot}8$ horse power of the water passing the gate or wheel race. As this class of water wheels has an efficiency of from 30 to 45 per cent. of the power value of the water, then a well constructed and true wheel running close to the sole board and curb, having a diameter of 12 feet by 3 feet in width, with 30 blades, each 9 inches wide, should have an efficiency of 40 per cent. or an available $1\frac{1}{2}$ horse power. Such a wheel may be made two or three

times the above width, with a corresponding gain in power, or with sufficient flow of water the blades may be made wider, and with a wider gate opening the wheel may be made available for anything up to 8 or 9 horse power.

THE PONCELOT WHEEL, Fig. 29, may be made of the same sizes and construction as the undershot wheel, with the exception that the buckets or blades are curved forward and the sole board also curved or inclined to fit the periphery of the wheel, it having been found that this form with thin metallic blades caught the water to a better advantage, showing an available effect or efficiency of from 50 to 60 per cent.



Poncelot Wheel, Fig. 29.

The computation for the horse power of this wheel is precisely the same as for the undershot wheel, as above; only that the efficiency is higher and is due to the peculiar curve of the buckets, which for best effect should be made of iron plates, and as shown in Fig. 29 should give an efficiency of 60 per cent. of the value of the gate opening as computed for the undershot wheel. In size the wheel may be three times the head of water, and in width up to twice its diameter.

THE BREAST WHEEL is a desirable form where a head of water can be made equal to one-half the diameter of the proposed wheel, or from 5 to 12 feet; or a 10 foot wheel for a 5 foot head and a 24 foot wheel for a 12 foot head, for best effect.

Fig. 30 represents the low breast wheel in its ordinary form with plain blades running in a curb to prevent waste at the ends of the buckets.

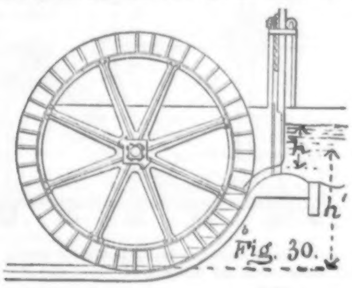


Fig. 30.

The volume of water flowing to a breast wheel may be approximately assumed as six-tenths of the velocity due to head, multiplied by the area of the gate.

For the theoretical velocity, $8·02 \times \sqrt{\text{height}}$ in feet from the center of the gate opening to the surface of the water in the race; and the actual volume in cubic feet per second by multiplying the area of the gate in square feet or decimals of a foot by six-tenths of the theoretical velocity, or

$\sqrt{2g \times h} = V$, and $V \times 0·6 \times A$ = cubic feet per second.

When the lip of the gate is depressed so as to give the water an impact upon the blades in the direction of their motion, one-half of the height of the water above the gate may be the point of measurement from the bottom of the wheel for the height in the formula for the horse power of the water issuing from the gate.

$$\text{Then the } \frac{\text{cubic feet} \times 62\frac{1}{2} \times \text{height}}{550} = \text{horse power}$$

of the issuing water.

This wheel as ordinarily constructed has an efficiency of about 50 per cent. of the value of the water power.

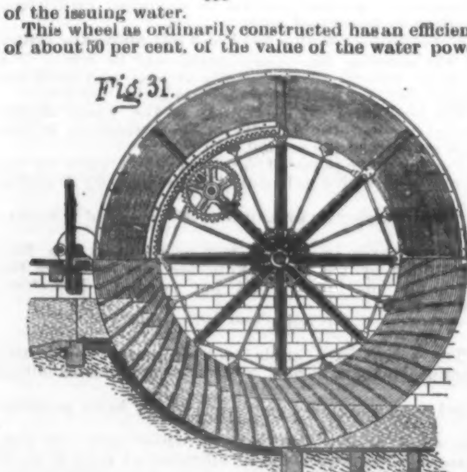


Fig. 31.

THE SAGEBEIN WHEEL is a low breast wheel of peculiar form and illustrated in its best form in Fig. 31. It is well adapted for heads of about ⅜ the diameter of the wheel, and for a large volume of water. The buckets are slightly curved and placed leaning backward and tangentially to a circle one-half the diameter of the wheel, open at the back, and of a width to prevent the spill on the inside of the wheel at the level of the water in the race.

The wheel should run close to a well-fitted sole plate, which may be curbed, or the buckets shrouded.

It is made to wallow in the tail race and to carry such a volume of water by its wide buckets and freedom from spill as to raise its efficiency to 60 per cent. of the value of the water power due the area of the gate and the whole head.

The power of this wheel is equal to 60 per cent. of the weir flow of the gate in pounds of water, multiplied by the height of the surface of the flood race above the tail race.

The weir flow for any depth up to 24 inches for 1 inch in width per minute may be taken from the table on page 12589, No. 788, SCIENTIFIC AMERICAN SUPPLEMENT, and by multiplying the quantity in the column opposite the given depth by the width of the gate in inches, will give the total flow of the weir in cubic feet per minute. Then the

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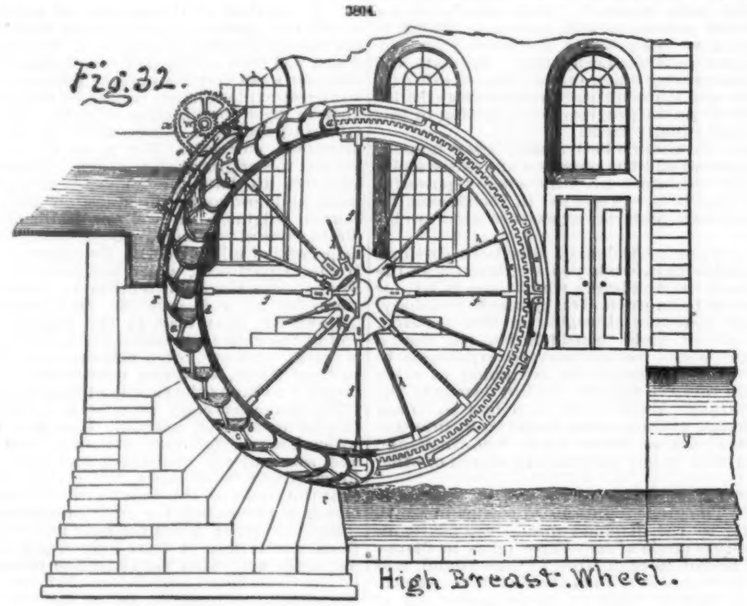


Fig. 32. High Breast Wheel.

$$\frac{\text{cubic feet} \times 62\frac{1}{2} \times \text{height in feet}}{33{,}000} = \text{horse power of}$$

water flow, and this power $\times$ 0·60 = the horse power of the wheel.

In this case the gate should be clear from the surface of the water, and is only used for regulating the speed or stopping the wheel.

THE OVERSHOT WHEEL has its peculiar province in the greater heights and smaller quantities of water flow, but cannot compete with the turbine and Pelton wheels in efficiency, nor well utilize the high heads for which these wheels are adapted. Its efficiency is about 70 per cent. of the value of the water flow. Within the range of its size, or from say 12 to 30 feet, a light overshot wheel may be made and set up in a home-made way that will do good work at reasonable cost. Nor is their size confined to the above figures, as wheels of this type are in use from 4 to 50 feet in diameter.

The power of the overshot wheel is derived principally from the weight of water flowing into and held by the buckets. The velocity of the stream from the gate by its low head should only be a little more than the velocity of the wheel periphery, which for best effect should be about 5 feet per second. The bucket should be so proportioned as to hold more than the required volume of water that is intended to be utilized at the best speed of the periphery, so that in computing areas, if the gate issues theoretically 3 cubic feet per second, and the wheel intended to run at 5 feet per second, then 5 feet of the periphery should hold the 3 cubic feet of water with sufficient surplus space as will prevent the spill taking place until the buckets have passed two-thirds of the half periphery.

The horse power of an overshot wheel is computed by multiplying the volume of water passing the gate in pounds per second by the height from the center of the gate to the bottom of the spill from the buckets in feet, and dividing the product by 550 and multiplying the quotient by the coefficient 0·70 for the horse power of the wheel. The volume of flow from the gate may be obtained by the formula for the current wheel.

THE SAW MILL WHEEL, so much in use in the lumber districts where water power is available, is a quick running wheel deriving its power more from the impact of water under the velocity due to higher head than other wheels of this class.

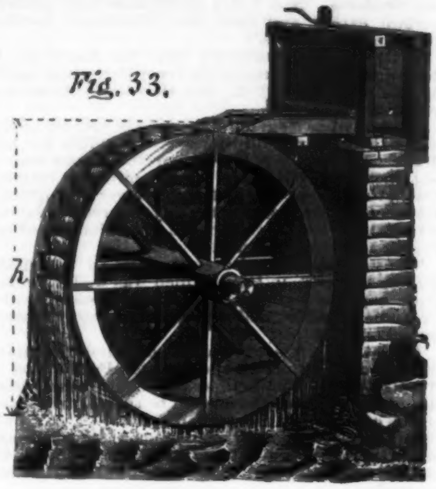


Fig. 33.

Its best effect, like other wheels, is at one-half the peripheral velocity of the water from the gate, the varying work of the saw affecting the velocity to a great extent.

The velocity of the water at the mouth of the gate opening, if it have a slightly taper form, will be, by the formula for theoretical velocity,

$$\sqrt{2g \times h'} \text{ or } 8·02 \times \sqrt{h'}$$

and this product multiplied by the coefficient 0·8 for this class of nozzle. Thus for a 10 foot head in the flume, the velocity would be

$$8·02 \times \sqrt{10} \times 0·8 = 20·28 \text{ feet per second.}$$

For speed of wheel, 3 feet in diameter, the variation in work would allow of from 50 to 75 revolutions per minute.

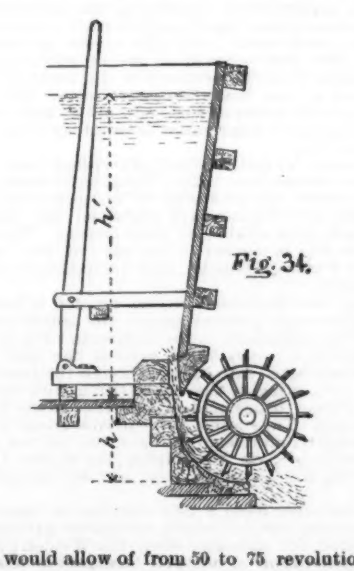


Fig. 34.

For the horse power we may assume a gate opening of 2 inches wide by 8 feet in length, or an area of 1·33 square feet. Then 20·28 × 1·33 = 26·97 cubic feet discharge per second. Adding two-thirds of the dia-

meter of the wheel, or h, Fig. 34, will make the total height of effective power 12 feet, and

$$\frac{26{\cdot}97 \times 62\frac{1}{2} \times 12}{550} = 36{\cdot}7 \text{ horse power.}$$

These wheels when well made with the outer edge of the blades beveled back and slightly curved on the face should have a coefficient of 60 per cent. of the gross power, or for the above wheel 22 horse power.

For an illustrated description and power of the HURDY GURDY, KNIGHTS, COLLINS and PELTON impact wheels, for high pressures, see SCIENTIFIC AMERICAN SUPPLEMENT, No. 454, and for method of laying pipe lines for the transmission of water for power purposes, see SCIENTIFIC AMERICAN SUPPLEMENT, No. 455, also the catalogue of the Pelton Wheel Co., for valuable tables of the power of water heads up to 1,000 feet.

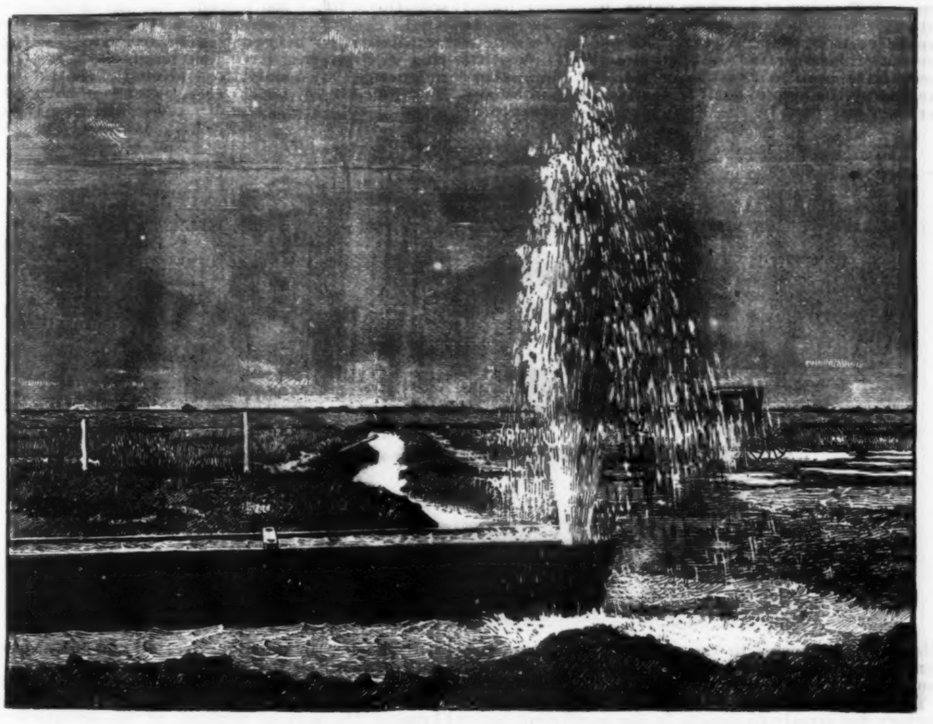
For the power of TURBINES, the catalogues of the various makers give the power, quantity and head of water, in tabulated forms, to suit every condition within their range. The general principle for finding the power of high water heads was fully explained in a previous chapter, from which a deduction of 15 per cent. may be made for the available power from the best Turbines and Pelton wheels.

A DAKOTA ARTESIAN WELL.

A CORRESPONDENT of the *Rural New-Yorker*, writing to that paper, says: The well of which I send a view was commenced in July, and the first part of October it had reached a depth of 1,030 feet. The pipe is six inches and the pressure about 150 pounds to the square inch. It is located about two miles east of Aberdeen. From it the owner expects to irrigate his farm of 800 acres. The advocates of artesian wells claim that we get rain enough here during the growing period to develop a good crop, if the ground is moist enough in the spring to give the plants a good start. Some of the fields on the above farm were flooded to such an extent last fall that a team could not venture on them.

Several parties are reported to be at work, sinking wells for the same purpose. They expect to have them ready before spring.

The supply of water appears permanent and bountiful, and if half the expectations of the people be realized, a new era will dawn upon Dakota. Already a number of farms, level and well located, are watered by means of artesian wells, and give excellent results. Of course, all farms cannot be irrigated. A farm must be smooth and with a gentle slope, with the water at the highest point, in order to give the best results; still there are many such that could be made very productive with abundant water.



A SOUTH DAKOTA IRRIGATING ARTESIAN WELL.

INDIAN CORN PRODUCT.

THE maize is first thoroughly cleaned in the usual way. The smaller grains, amounting to one-third of the entire bulk, are sifted out and the remaining larger grains then thoroughly moistened in order to toughen the germs and make them more readily detachable from the "grits" or starchy parts of the grains. The damp maize, containing about 25 per cent. of water, is passed between a roller, making about 500 revolutions per minute, and a fixed segment, the curvature of which is the same as that of the roller. The roller may have a diameter of 20 to 30 inches. The fixed segment and roller are provided with concave undercut flutes or grooves, the edges of the flutes pointing upward and downward respectively. The flutes of the roll have a lead of about four inches. The distance between the edges of adjoining flutes is about one-sixth of an inch in the case of the roll and about one-eighth of an inch in the case of the segment. By means of this apparatus the maize is degerminated more thoroughly, and less fine meal is produced, while a greater proportion of husk is left on the "grits," thus leading to better drainage in the mash tun. The mixture of grits and germs is freed from flour by sifting, the germs being subsequently removed by treatment in any suitable washer. The degerminated grits are cooked by boiling or any other known means, a suitable yeast food being added at this stage. The grits are then partially dried and passed between rolls under great pressure, the rolls revolving at the relative speeds of four and five respectively. By this means the flakes are made thinner and larger. Finally the flakes are torrefied, when they are fit for use.—*J. White, Belfast.*

KAINIT.

THE use of kainit as a fertilizer is almost universal in Germany, and has extended largely into other parts of Europe, the coffee plantations of Brazil and Ceylon, and is now commanding the earnest attention of farmers in the United States. Its use as a fertilizer has increased to an enormous extent from a comparatively small beginning, and has attained an importance equal to that which Peruvian guano reached years ago. Thousands of tons have been exported annually, and the quantity is increasing rapidly.

An analysis of kainit shows that it contains sulphate of potash, 24·80 per cent.; sulphate of magnesia, 14·30 per cent.; chloride of magnesia, 12·63 per cent.; chloride of sodium (common salt), 32·00 per cent.; moisture, 14·36 per cent.; insoluble matter, 1·92 per cent.; total, 100. Guaranteed 23 per cent. sulphate of potash.

It is chiefly valuable for the potash contained in it, which is an ingredient of every cultivated plant, and without which none can grow. Potash is necessary for the formation of starch in the leaves, stalks, etc., for without it the plant cannot assimilate the materials needed for its growth, nor show any increase in weight. It is a well known fact that all plants absorb potash from the soil—some to a greater extent than others; as, for instance, hay, clover, corn, tobacco, hops, potatoes, and roots absorb largely, while grain crops exhaust it less.

Commercial fertilizers, such as superphosphates, bone, fish, and slaughter house refuse, etc., contain little or no potash. The well known Peruvian guano yields but a small percentage. It will be interesting in this connection to note carefully the following remarks made by Dr. Franz Giersberg, a celebrated professor of agriculture in Germany, in lectures delivered by him, by order of the German government, before agricultural societies throughout the empire. After alluding to the nourishment of plants in general, and the most beneficial materials needed for such nourishment, he says: "There is no doubt about the fact that the application of bone dust, as well as other phosphates, to the soil, may and will produce large yields for several years, the soil, by reason of such application (mainly in connection with nitrogen), being stimulated to more vigorous action. The soil yields largely of the nourishment which, in addition to phosphates, all plants necessarily require, but as no compensation is allowed for the absorption of the former, we, but too often, experience the result that where a soil receives only phosphate manuring for a length of time it will become eventually entirely unproductive. Phosphate manuring only restores to the soil the one, omitting the other nourishments needed for the active thriving of the plants, and as a consequence the soil and crops deteriorate in quantity and quality. One-sided manuring will not produce satisfactory results for any length of time, but we may justly claim and expect for the use of potash salt (kainit) a larger and better fertility, since potash is absorbed by most plants in double, even four times, larger quantities than phosphates.

Thus it will be seen that potash is absolutely essential as a plant food, but the expense attending the artificial production of it, by boiling sea water, would be too enormous to entitle it to serious consideration. Nature, in anticipation of its exhaustion from our lands, has made ample provision for a plentiful supply, by a process of evaporation of sea water on an enormous scale in Germany, and as a result, we have kainit, containing the nourishment needed, at a trifling expense. There are furnished abundant indications that in the older States the available supply of potash has become greatly reduced, and must be replenished, or the crops will fail. We are now passing through the same costly and bitter experience that the farmers on the other side of the Atlantic had to encounter, and we must seek the same remedy that they applied so successfully—kainit.

The value of sulphate of magnesia contained in kainit, as a plant food and an aid in the development of seed, has not received the careful consideration that its great importance deserves. Experiments made from time to time prove that the quantity of magnesia in seed greatly exceeds the quantity in straw, and furnishes ample evidence that it is indispensable to the perfect formation of seed. For instance, we find in the ashes of grains of wheat 12 per cent. of magnesia, in conjunction with 30 per cent. potash; in rape seed 12 per cent. magnesia and 23 per cent. potash, and in all other seeds a similar proportion.

It is a great aid in the proper and thorough diffusing of potash through the soil, bringing it within reach of the roots, and at the same time effecting a prompt and complete action of the ammonia of manures used.

Chloride of sodium (common salt) is useful in rendering other materials available.

In order to allow the chlorine combinations contained in kainit, which may be injurious to some plants, to lose their effect on such plants, it is recommended that kainit be applied as long as possible before the seed is sown, as, for instance, in the late fall for the following season's crop, thereby securing the benefit of all rain or snow falling in the meantime, and a consequent deep and thorough incorporation of the kainit ingredients through the soil—those which may be injurious sinking deeply and beyond the reach of the roots of plants to be grown, those which are beneficial and nourishing being within ready access of all the roots, and not confined in single places. This method of applying kainit will prove itself highly advantageous, whether alone or in combination with stable manure, farm refuse, phosphates, or other fertilizing materials, and should be strictly adhered to, unless positively impracticable.

It is recommended by many who have made a study of the effects of kainit that it be mixed with an equal part of lime, as experiments have proved such application to have been highly advantageous, not only in the yield, but in surely overcoming the possible danger of any injury to the plants by the chlorine combinations above mentioned.

It may be safely laid down as a rule that calcareous (lime), light and sandy soils, and those composed largely of decayed vegetable matter, are deficient in potash, while clayey and loamy soils are more plentifully supplied. In either of these cases, however, the supply necessary for perfect growth may not only be reduced, but almost exhausted by constant cropping.

Regarding the quantity of kainit necessary for one acre, and the proportion to be used in combination with phosphates, etc., it is recommended that from 200 lb. to 400 lb. be used alone, spread broadcast, as long before crop is planted as possible; and at the proper time one-half that quantity of phosphates, if latter is needed. To all farmers, whether acquainted or not with kainit manuring, we will say that it will be better to use little and often than a greater quantity at long intervals.

For the benefit of those who may not be acquainted with kainit, its use and results, we will add the following notes regarding the results on different crops after its application.

For oats, wheat, corn, and the like, an application of 300 lb. kainit in the fall, and the proportionate quantity of phosphate in the spring, per acre, showed, by many experiments, vastly improved yields over former manurings, both in the strength and stand of the straw and size of the grain.

Kainit, whose fitness as a prominent fertilizing mineral manure is world-wide known, will also act when applied to the soil in preventing, to a large extent, the disastrous effects of the disease known under the name of "rust."

This disease is visible to the naked eye by red spots on the leaves of plants, especially on wheat. By scientific researches made in Germany and other countries, it has been established that these spots are fungi, parts of which detach themselves in time, are carried away by wind, and will spread the disease when settling down.

Stable manure will, of course, contain more or less of these injurious matters. For this reason, stable manure ought to be little used in wheat growing, and preference given to artificial manures. These contain a combination of acids that will weaken or even expel the rust.

This is so well known in Germany that no farmer in that country would think of raising wheat crops of stable manure, but they all apply artificial manures, among which the potash salts are foremost.

For beans, peas, hops, beets, potatoes, and the like, the quantity generally recommended is about 300 lb., and the result will be pleasing and profitable. The yield, particularly of beets, was striking, and where the manufacture of beet sugar is carried on the introduction of kainit to the beet farms will be productive of immense good, as its use will amply repay its cost. These farms may require more than the above quantity of kainit, as this crop exhausts potash from the soil in large quantities and very quickly.

For garden vegetables it seems, in many cases, that a larger quantity of kainit is recommended than the average needed for other growths, and the results excellent. In this connection we would like to call attention to the profit (pecuniarily) in its use on asparagus. Repeated experiments show that a rather large quantity was needed, and the asparagus grown was very large and of excellent quality. For cucumbers it is also particularly beneficial.

For fruit trees and berry vines, spread the kainit around the trees, etc., and rake the ground evenly and level. If too late to do it, or not convenient, the next best plan is to dig six to ten holes, say one to two feet deep, about one and a half to three feet from the trees or vines, and pour the kainit in these holes.—*Kuhlow.*

ONE of the problems of the future is the transformation of carbon energy into light upon the same principle that the glow-worm and firefly give their light, and when a single pound of combustible material will furnish as much light as is now obtained from a ton of coal.

IMPROVED STORAGE BATTERY SYSTEM.

ACCUMULATOR cars have been appearing with a certain wearisome periodicity ever since the experiments of Faure evolved the modern storage battery. It is so seldom, however, that one can conscientiously say anything good of them that an occasion like the one about to be described is a somewhat noteworthy event in electrical circles. On Monday, May 4, a public test of the Waddell-Entz storage battery car was held in Philadelphia, and its success was so unusual as to attract very widespread attention. The inventors of the apparatus, Messrs. J. B. Entz and Montgomery Waddell, of New York, have been working quietly along, making experiments for the past year, and have made some preliminary tests with a car equipped with their devices on the Brooklyn and Coney Island road. About a month ago the car was put on one of the Philadelphia lines near Germantown Junction, and has been undergoing a series of experiments ever since. These have been so successful as to warrant the public exhibition that has just been held.

Unlike most storage battery cars, something more was involved in the present one than a storage battery warranted not to buckle and a motor of crude and unusual design. The features of the Waddell-Entz apparatus are three: First, the use of an alkaline accumulator; second, the employment of a particularly light slow speed motor; and, third, practical arrangements for utilizing the motor as a dynamo on down grades to recover a certain proportion of the energy used in storing the battery. Nearly all the work that has been done on accumulators has been devoted to the lead type, in which the electrodes are leaden grids of infinitely various forms packed in one way or another with oxides of lead. The electromotive force of such cells is high, as every electrician knows, between 2 and 2·4 volts per cell; but the weight is enormous and the durability anything but what could be desired.

The deterioration of lead storage batteries occurs partially through irreversible chemical processes going on in the cell, and also through the mechanical action produced by these chemical processes on the active material of the plate, the result being that the grids are, from a swelling and distortion of the plugs of active material within them, twisted out of shape so that the battery is short-circuited. This fault occurs in the positive plates and is known as buckling; it is the peculiar difficulty with ordinary storage batteries. Whenever one attempts to force the output of a cell and draw from it an unusually large current, the result is a tendency to buckle the plate, and when, as in street car work, severe demands are made upon the battery many times in the course of a trip, the effect is disastrous, and a very few months is found to destroy the usefulness of the cell, either through buckling or through disintegration of the active material.

In experiments carried on by a very large number of people all over the world during the last decade, the uniform fate of positive plates has been found to be rapid disintegration as soon as they were put to any severe service. Of course, there have been occasional exceptions, but the fault is so general as to be wellnigh universal, and has its origin in the nature of the chemical actions in the cell and their effect upon the physical characteristics of the active material. The weight of the average lead accumulator is about 100 pounds per h. p. hour stored, and the efficiency under ordinary conditions somewhere near 80 per cent., this latter depending almost entirely on the rates of charge and discharge and the care that is taken of the cell.

The inventors of the system under discussion, for reasons like those enumerated, avoided the lead type of battery and adopted a very promising kind of accumulator that sprung into notoriety in France some two or three years ago; this is the alkaline accumulator brought out by Desmazures and his associates. It is, chemically, strikingly similar to the Lalande-Chaperon battery, known here with slight modifications as the Edison-Lalande. The alkaline accumulator has for its two metallic elements copper and zinc, and for the electrolyte caustic potash. The zinc is deposited upon iron electrodes, while the copper is exceedingly porous and capable of very ready oxidation.

Fig. 1 shows in diagram the character of the cell. The solution of the cell is really potassium zincate. The action on charging is to deposit metallic zinc on the iron electrode, which latter is generally in the form of a tinned gauze, and to oxidize the porous copper. On closed circuit the zinc is dissolved with the formation of potassium zincate and the oxide of copper is reduced. A porous partition is placed between the two elements, originally made of parchment paper. The electromotive force of such a couple is small, 0·8 to 0·9 of a volt, but the chemical action is almost completely reversible and the output very great in proportion to the weight.

The Desmazures accumulator was made with a plate of copper obtained by the compression of copper dust, giving a consistent mass, though the result showed it somewhat lacking in the necessary porosity. The batteries were adopted by the French government for the important experiments carried out on submarine torpedo boats, and furnished the power for the operation of the La Gymnote, that made something of a sensation in the naval world a little over a year ago. The outcome of a great deal of experimentation showed

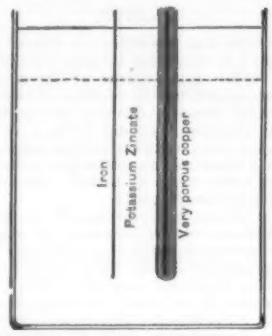


FIG. 1.—WADDELL-ENTZ STORAGE CELL.

that the efficiency of the alkaline battery was practically the same as that of a lead battery, while its weight could be easily reduced to a point unapproachable by any practicable form of the old accumulator. The weight of the alkaline accumulator per h. p. hour proved to be from 55 to 60 pounds, and there was nothing like the buckling that has proved so fatal to the positive plates of ordinary storage batteries. Such is the battery that Messrs. Waddell and Entz took up with a view to reducing it to a thoroughly practical form. Difficulties of a serious nature have been found with it, notably a great increase in resistance of the copper positive plates after a little use, and a serious amount of local action on open circuit. These great faults have been in a very large measure eliminated; the first by the employment of vastly more porous copper than was used by the French experimenters, thus allowing freer access to the reducing agent and preventing the irreversible oxidation that had before been found.

The second difficulty was in the original Desmazures battery due largely to defects in the parchment paper envelope, which in the present case is replaced by a textile one that gives vastly better results. In the Entz battery, too, the porous copper is furnished with a permanent backing of dense copper that is entirely unaffected in the action of the cell, and consequently keeps up the conductivity. Fig. 1 shows in diagram the general character of the resulting cell. The copper electrode is made with a dense copper core surrounded by exceedingly porous copper, and the whole inclosed in a textile covering; the liquid is potassium zincate, and the other electrode is of iron, permitting the deposition of the zinc. As a matter of fact, numerous plates are employed in each cell, just as in the ordinary lead battery, and the walls of the cell itself are of iron, and form a portion of the negative pole.

The result of these small but important changes made by the American inventors is a battery that, like its prototype, weighs about 55 or 60 pounds per h. p. stored, has an efficiency equivalent to that of the best lead storage batteries, and a power of resisting enormous discharges and working under very severe conditions that is unequaled, so far as we know, by any of the earlier types. Apparently, the faults of the Desmazures battery have been successfully overcome. In the car used in Philadelphia, 100 battery cells, weighing, complete and filled, 30 pounds apiece, and each $5 \times 7 \times 11$ inches, were employed, giving from 75 to 80

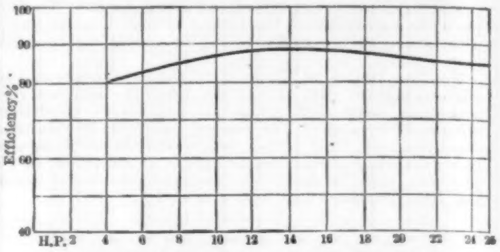


FIG. 2.—EFFICIENCY CURVE OF THE WADDELL-ENTZ MOTOR.

volts at normal output. This battery is capable of delivering as high as 300 amperes without the evolution of gas or serious heating. It is stored under the seats of the car, as is the usual practice, and is, for the purpose of governing and recharging, divided into several sets of cells. It will thus be seen that the battery equipment is very light, weighing, as it does, only about 60 per cent. as much as a lead battery of equal capacity. The gain in weight of battery per car is something like 1,500 pounds; the car is driven by a single carefully designed low speed motor. It is of unusual design, inasmuch as the armature is a Gramme ring with internal fixed field magnets; the latter are magnetized by a single coil around a central shank. Two four-armed spiders upon the ends of this give the alternating north and south poles; the ring armature is $21\frac{1}{2}$ inches in diameter over all and has a depth of core of about $1\frac{1}{2}$ inches. It is wound, of course, with a heavy wire, for it is designed for a low voltage and large quantity of current. There are four carbon brushes, the several portions of the armature being thrown in parallel with each other; the whole is inclosed in a frame of non-magnetic material. Fig. 3 gives an excellent idea of the appearance of the machine and the methods of its support, one side of the frame being supported on the axle shown by dotted lines, the other upon a transverse beam on the truck, also shown by dotted lines in the cut. The armature speed for a car speed of ten miles is about 450 revolutions per minute, and the power is transmitted to the axle through a single pair of gears, the speed reduction being about five to one. The armature pinion is case-hardened and acts on a wooden axle

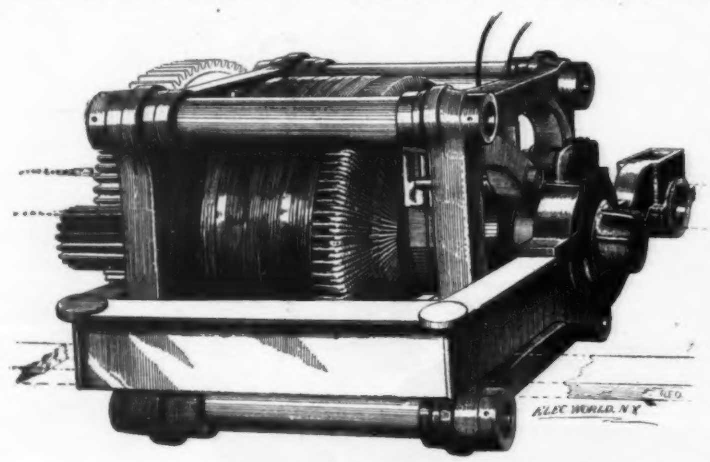


FIG. 3.—THE WADDELL-ENTZ STREET CAR MOTOR.

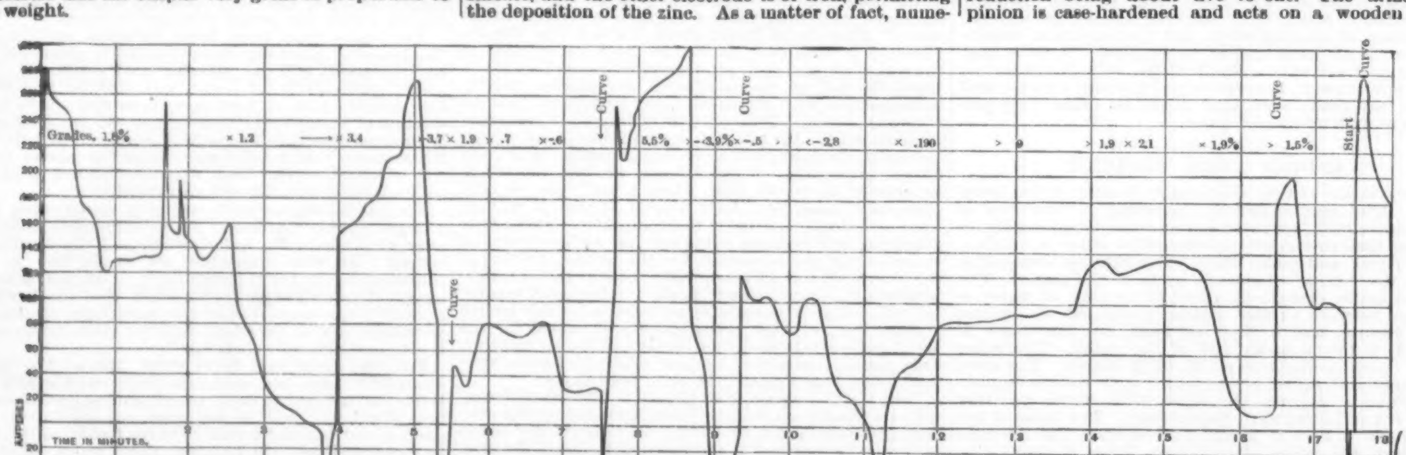


FIG. 4.—CURVE SHOWING THE CURRENT USED BY THE WADDELL-ENTZ MOTOR DURING A TRIP OVER A THREE MILE TRACK.

gear, so that the car runs very quietly. The advantages of this peculiar type of motor are in the large and well ventilated armature, giving a powerful torque, and permitting the use of very heavy currents without excessive heating, and, second, in the simple form of the field magnets enabling magnetism to be obtained with comparatively small expenditure of energy. The actual maximum efficiency of the motor is satisfactory without being phenomenal. The machine was designed, however, to give its maximum efficiency at something like its average output. Fig. 2 shows its efficiency curve at various loads. The motor being nominally of 20 h. p., its point of maximum efficiency is at about 15 h. p., and even at 15 h. p., its normal load, the efficiency will be seen to be 80 per cent. This is not a remarkable figure, but it gives a good all-around commercial efficiency even under widely varying loads. The use of a single motor once geared is in itself a decided advantage, as it both increases the commercial efficiency by avoiding multiplicity of gears and also reduces the working weight of the equipment. The motor and the regulating devices together weigh less than 1,500 pounds, with the result that the total weight of batteries, motor, and regulating appliances in this Waddell-Entz car is less than that of the motor equipment of the standard cars used on the trolley system. This means a very decided saving in power, for one of the besetting sins of the storage battery system has been the excessive weight of equipment, every extra pound of which meant extra coal burned at the power station. Of course the same or similar motors could be used for the trolley system if desired, although such has not been the usual practice. The total weight of the copper in the motor is 130 pounds, a very satisfactory result for a motor intended for such exceedingly heavy currents. The regulating appliances of the car are interesting. The platform switch has six steps. Of these the first throws on the batteries, four in multiple to start the car, the second changes this arrangement to two in multiple, the third throws all the cells in series, while the fourth and fifth cut out sections of the field, and the sixth reverses the motor on its lowest speed.

The motors when the car is running down hill can operate as dynamos and restore energy to the batteries. This feature of the system is of practical use of course only on roads with perceptible grades, but under such circumstances it is undoubtedly somewhat effective, possibly saving as much as 10 per cent. of energy. The road over which the trial trip was made is almost exactly three miles in length, giving a six mile round trip for the car, and the power required to charge the batteries for the work is very nearly six horse power hours, practically one horse power hour per car mile. The total capacity of the batteries is of course much greater than this, sufficient for perhaps half a day of ordinary service. This result of one horse power hour per car mile at the power station is immensely satisfactory; it is unquestionably better than has been usually obtained by storage battery cars, and compares very favorably with the output shown to be necessary on trolley roads, which, however, it should be said, have heavier grades and a heavier car equipment than the one we are considering. The trial trip was a thorough and complete success. The car ran smoothly and regularly, and its motion down grades was reported to be exceedingly easy, owing to the reversal of the motors and the braking action of their use as dynamos. In the same way stopping is accomplished within the length of a car, and very smoothly, owing to the device just mentioned. Fig. 5 shows a view of the complete car with which the experiments were made, and Fig. 4 a diagram of the output required at each point of the test run over the road. The readings were taken with Weston ammeters and voltmeters each ten seconds and the result shows clearly the ability of the batteries to stand a very heavy output without serious drop in their power. The portions of the curve below the axis represent, of course, periods during which energy was being restored to the battery. It will be seen that the running speed in this test was 10 miles per hour, the three miles being covered in 18 minutes. Altogether this alkaline storage battery motor system seems to be a very useful addition to the methods of electric traction, certainly the most promising that has appeared for some time in the way of proper equipment for city service. Of course time alone will tell its success when operated by unskilled labor under adverse conditions, but the results obtained are certainly such as to warrant a considerable degree of encouragement to the advocates of storage battery traction.—*Electrical World.*

FIG. 5.—CAR EQUIPPED WITH THE WADDELL-ENTZ MOTOR.

THE ANALYSIS OF DEGRAS.

By F. SIMAND.

GENUINE degras contains a substance described by Jean as resembling a resin, which the present author terms *degras producer* or *substance*, upon the quantity of which the quality of the degras depends; the greater the proportion of it in any sample, the higher is the quality of the article. This substance in the impure state is of a brownish black color, but after purification forms a light brown mass, which contains nitrogen, dissolves very readily in alkalies and ammonia and is precipitated from these solutions by acids in the form of a light colored flocculent mass. Hot water, especially when it contains a little acid, dissolves the substance to a certain extent; it is also soluble in alcohol, glacial acetic acid, and aniline, almost insoluble in ether, and quite insoluble in light petroleum and benzine. It does not melt on heating, and is chiefly found in genuine degras from chamois leather, in the process of preparing which it appears to be formed. It occurs, however, in greater or smaller amounts in almost all train oils, and is of great value for tanning purposes.

In order to determine the amount of this *degras substance* present, 20–25 gms. of degras, according to the amount of water contained in it, are saponified on the water bath with 5–6 gms. of caustic soda dissolved in about 10 c.c. of water and 50–60 c.c. of alcohol, loss of alcohol being hindered as much as possible by a small funnel placed in the neck of the flask. As soon as the whole is dissolved, the alcohol is driven off and the soap dissolved in water, the fatty acids, together with the *degras substance*, being then separated by hydrochloric acid. The liquid is then heated until the fatty acids form a clear layer at the top, the whole allowed to cool, and the aqueous solution poured away from the cake of fatty acids. This aqueous solution contains a little of the *degras substance* in solution, and is, therefore, neutralized with ammonia and evaporated. The fatty acids, which contain the degras substance, are extracted several times with boiling water to remove hydrochloric acid and the wash water neutralized with ammonia and added to the first filtrate. These combined washings are evaporated to dryness, the residue dissolved in a little water, and a slight excess of hydrochloric acid added. The precipitated substance is filtered off, washed until free from hydrochloric acid, dried on the filter, and added to the fatty acids, etc., which have in the meantime been dried at 105° (this drying is not absolutely necessary). The united mass is placed in an Erlenmeyer flask and covered with 100–120 c.c. of light petroleum, boiling below 70°. The fatty acids dissolve, whereas the degras substance and a small amount of albumenoid matter remain undissolved. The liquid is filtered, the residue washed with light petroleum, the filtrate being evaporated and the fatty acids weighed. The residual mass, which was insoluble in the petroleum, is treated with hot alcohol, in which the albumenoid matter is insoluble, the liquid filtered and the degras substance finally weighed after the evaporation of the alcohol.

A sample of degras can only be considered genuine and pure when it contains at least 12 per cent. of this degras substance, the amount of water present being 20 per cent. In some cases as much as 16–17 per cent. is present.

To determine the *amount of water*, 25 grms. of degras are weighed into a tared porcelain basin, provided with a short thermometer to be used as a stirring rod, 50–100 grms. of train oil added to render the mass more fluid, and to prevent spurting, and the whole heated on a wire gauze to 105° C. until no more gas bubbles are given off; the loss of weight is due to water. A certain amount of other volatile matter is lost with the water, but this error does not exceed 0·5 per cent.

The train oil or other oil (vaseline oil is not well adapted for the purpose) which is used must have been previously heated to 105°, if necessary, with the addition of water until all volatile matter has been removed. The amount of water varies from 15–30 per cent. in products obtained by the French process, and from 20–40 per cent. in leather dressers' degras.

The *ash* is determined by heating 25 grms. of degras until all the water has been driven off, the mass being continually stirred with a glass rod, cleaning the rod from adhering fat by a piece of filter paper, lighting the degras by means of this paper, and heating the residue to redness.

It varies from a few hundredths per cent. in the French product to about three per cent. in leather dressers' degras.

If, through careless work, any sodium or ammonium salts be left adhering to the degras substance, their presence being shown by the formation of crystals, the whole is dissolved in a little ammonia, water added, and then a slight excess of hydrochloric or sulphuric acid. The precipitate is washed on a weighed filter paper with cold water and weighed.

The author has investigated the properties of this degras substance and concludes that it occurs in degras as a substance resembling the fats, which, like the latter, is readily soluble in petroleum and with difficulty in alcohol; on saponification and decomposition with acid, a substance resembling the fatty acids, and, like them, soluble in alcohol, is formed.

The emulsifying power of degras depends upon the amount of degras substance contained in it. Further researches have led the author to conclude that the compound of this degras substance which occurs in degras is either decomposed by the leather fiber, which then combines with the liberated degras substance, or is taken up unaltered by the fiber. In chamois leather the fiber is more intimately and firmly combined with the degras substance than in tanned leathers, in which the fiber is saturated with tannin, and therefore shows less tendency to combine with another substance. The action of the degras substance in genuine degras, therefore, is most thoroughly exercised with leathers which are tanned soft and contain fiber, which are to a certain extent crude and in a position to combine with it; the prepared leather will then be very soft and resemble chamois leather.

In connection with his examination of genuine degras, the author also communicates the method adopted by him in investigating artificial makes of degras. In the course of such an examination he determines (1) The degras substance, arising from genuine degras, present in the sample or from train oil; (2) Suint; (3) Vaseline oil; (4) Resin, colophonium. Water and ash are determined as in the genuine products.

ESTIMATION OF THE DEGRAS SUBSTANCE.

5–10 grms. or more of the sample are saponified in a flask, the fatty acids precipitated by hydrochloric acid, washed and treated with ether. The degras substance which remains insoluble in them is dissolved in alcohol and estimated as already described.

ESTIMATION OF WOOL FAT.

The ethereal solution is placed in a weighed flask, the ether evaporated and the residue boiled with 1 to 1½ parts of acetic anhydride for 1–2 hours, the flask being connected with an inverted condenser. Water is then added and the precipitate repeatedly extracted with water to remove acetic acid, after which it is dried, and the mixture of acetic ethers of the fatty acids and of cholesterin, etc., thus obtained dissolved in 15 parts of boiling alcohol (75–150 c.c.), cooled, filtered from the cholesteryl acetate which separates out, and twice again dissolved in 15 parts of boiling alcohol, to remove vaseline oil as completely as possible. The cholesteryl acetate is then dissolved in ether, the ether evaporated from the clear solution, and the residue weighed and calculated to wool fat.

The author has examined 7 samples of commercial wool fat, in order to ascertain how much cholesteryl acetate these yield. He found a minimum of 7·59, and a maximum of 19·43, the average being 14·05 per cent. According to this the factor for calculating the amount of wool fat would be 10·42, 5·15, or 7·11. Thus, for example, 0·4 grm. cholesteryl acetate obtained from 10 grms. of degras would correspond to either 20·60 or 41·68 per cent. of wool fat, or taking the average number, 28·44 per cent. Chemists intrusted with such analysis will be able to tell from the appearance of the fat separated from the degras and dried, and from its melting point, whether 20 or 40 per cent. are present. In any case the presence of wool fat can be detected with certainty and estimated with sufficient accuracy. A further indication of wool fat in a mixture of fats is the lustrous surface of the solidified fat, or, if this does not solidify, the lustrous and non-crystalline surface of the solid fatty acids obtained on saponification; the smell of wool fat, especially when the fat is rubbed on the hands, can also be easily recognized. It must be borne in mind that small quantities of cholesterin also occur in genuine degras and in fish oils; the fatty acids of these, however, solidify to a crystalline state, or, from some of the fish oils, not at all, so that any mistake is impossible.

The *vaseline oil* is estimated by evaporating off the alcoholic solution, which contains the acetylated fatty acids, the vaseline oil, and the resin. The residue is saponified with caustic soda, glycerine added (Nitrete, Benedibt, Analyse der Fette und Wachsarten, p. 119), and the vaseline oil extracted by shaking with light petroleum. The substance thus obtained always contains soap, which is removed by agitating it with water, after the removal of the petroleum, adding a little magnesium sulphate, which forms an insoluble soap, and again extracting with light petroleum.

ESTIMATION OF COLOPHONIUM.

The residual soap solution is decomposed with hydrochloric acid, the precipitate washed, the fatty acids and resin dissolved in alcohol, the alcohol evaporated off in a weighed vessel, and the residue weighed. The resin acid is then determined in an aliquot part by the method of V. Hubel and Stadler. The silver salts are extracted with ether, in which the salt of the resin acid is soluble, and the latter is then decomposed in ethereal solution with hydrochloric acid. The weight of the resin can then be determined by evaporating the ether.

The author examined one sample from a well-known German works, which from its price should have been genuine chamois degras, but really consisted of water 15·8 per cent., wool fat not less than 20 per cent., vaseline oil 9·71 per cent., resin 10 per cent., fish oil 44·46 per cent., in which about 1 per cent. of degras substance is contained. The article was, therefore, an artificial product, and had never been near chamois leather.

A French article contained water 17·69 per cent., wool fat 35 per cent. (about), vaseline oil 10 per cent., genuine anhydrous degras about 25 per cent., fish oil, palm oil, etc., 12·31 per cent.—*Chemiker Zeitung.*

DISSOCIATION PHENOMENA.

IN the year 1860, A. W. Von Hoffmann published a paper in conjunction with H. Buff, in which it was stated that carbonic acid gas is gradually decomposed by the passage of a series of electric sparks through the gas, and that after a time the carbonic oxide and oxygen (the results of the dissociation) recombine with explosive violence. After thirty years, Von Hoffmann has returned to these experiments, and there is another paper by him in the "Berichte der deutschen Chemischen Gesellschaft," xxiii., p. 3303–3319, from which we make the following abstract.

On repeating the experiments made in 1860, it was found that the explosion only occurs under certain special conditions. From six to ten c. c. of previously dried carbonic acid gas, under a pressure of 650–700 mm., are brought into a stout glass tube standing over mercury; a short piece of platinum wire is fused into the shorter limb of a thin U-shaped tube (Fig. 1), the

FIG. 1.

tube is filled with mercury, and a second piece of wire wound spirally round the outside of the shorter limb, which is then passed up into the vessel containing the gas (Fig. 2); in this way the length of the spark may be easily regulated; in general it should be 2·5–3 mm. Connection is made by two wires dipping into the mercury contained in the U-tube and trough respectively.

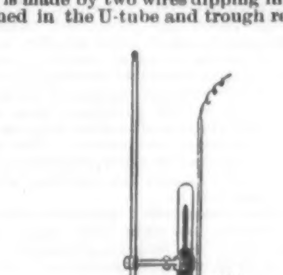


FIG. 2.

The electric current is obtained from two Bunsen's elements of medium size, which are connected with a Rhumkorff coil and a small Leyden jar, the coil being 30 cm. long and 10 cm. in diameter (Fig. 3).

FIG. 3.

The first explosion usually occurs after 15–20 minutes, and the subsequent ones at shorter intervals, since the regeneration of the carbonic acid gas is not complete.

The dissociation of carbonic acid gas may be shown by passing the gas through a glass tube, in the middle of which two platinum terminals are fused; a series of sparks is allowed to pass, and the issuing gas collected over potash. Part of this gas dissolves, and the remainder will be found to be explosive.

The accompanying illustration (Fig. 4) shows a form of apparatus which may be employed for the purpose of showing the dissociation of steam at varying pressures.

The wide glass tube is 2·5 cm. in diameter and 20 cm. in length; the lower tube is 1 cm. in diameter and 40 cm. in length. The apparatus is filled with moist mercury and heated with steam. Instead of fixed platinum terminals, the U-tube and wire described above may be employed. No regeneration of water occurs in this case.

The experiment may be varied by allowing the apparatus to cool while the electric current is continued; the dissociated gases gradually combine, and the whole tube becomes refilled with mercury. The best current to use is one obtained from three Bunsen cells, with the coil and Leyden jar as before.

Steam may also be dissociated by means of a glowing white-hot spiral of platinum wire; the two ends are connected with accumulators, steam is passed over the coil and the mixed gases are collected over cold water, which serves to condense the excess of steam.

Experiments in the dissociation of gases and vapors by means of the silent discharge show that ozone is produced by the decomposition of carbonic acid gas, the result obtained by Andrews, Tait, Brodie and others being thus confirmed.

Steam may also be decomposed by passing it through a Siemens ozone induction tube or by the use of the modified apparatus devised by Berthelot. Various experiments have shown that the explosive gas

FIG. 4.

obtained is really derived from the steam and is not due to electrolysis.

Von Hoffmann also confirmed Berthelot's results on the decomposition of ammonia by means of the silent discharge, and found that the vapors of methyl alcohol, ethyl alcohol, and ethyl ether may also be dissociated by means of the silent discharge.—*Electrical Review.*

THE NATURE OF WOODY FIBER.

By Prof. ANTON IHL.

IN order to explain the chemical processes by means of which pure cellulose can be prepared from wood and other vegetable substances by the soda and sulphite methods, it is first of all necessary to know what are the constituents of woody fiber.

Wood consists of about equal parts of cellulose and lignine. The nature of the latter of these substances is not yet accurately known. Singer has found in wood fiber vanillin, coniferin, wood gum, and a substance which is insoluble in water, and is colored yellow by hydrochloric acid. Wood is also colored yellow by aniline sulphate and phloroglucol, which is more delicate. The most delicate reagent of this class is, however, an alcoholic solution of pyrol. In the year 1885 I published a research in the *Chemiker Zeitung* (1885, 9, 266), in which I showed that in general phenols give well marked color reactions with woody fiber in the presence of acids. Orcinol and resorcinol in particular were found to be the most delicate reagents for this purpose, employed in alcoholic solution along with hydrochloric acid. Since none of these wood reactions agree with the reactions of vanillin or coniferin, it follows that other substances are also present in the wood, and it becomes the first object of investigation to ascertain what these are.

In connection with my work on the color reactions of ethereal oils (*Chem. Zeit.*, 1889, 13, 264) I found that some of these, such as the oils of cinnamon, cloves, and pimento, give the same reactions as lignine. This is especially the case with oil of cinnamon, which consists of a hydrocarbon and cinnamaldehyde.

This last named substance, however, gives almost the same reactions as lignine with pyrol, aniline sulphate, phloroglucol, orcinol, resorcinol and other phenols, sulphuric acid, urea, lepidene, and antipyrine, so that it is most probable that it is a constituent of woody fiber (*Chem. Zeit.*, 1889, 1, 3, 560, 881).

In favor of the view that cinnamaldehyde is a constituent of wood is the fact that the urine of graminivorous animals contains hippuric acid in large quantities. Thus, for example, the urine of oxen fed on oats and wheat straw contains 2·1–2·7 per cent. of hippuric acid. It is, moreover, known that cinnamic acid taken internally is excreted as hippuric acid (Beelstein, Org. Chem., II., 899). The presence of hippuric acid in such urine is therefore to be explained by the oxidation of the cinnamaldehyde of the fiber to cinnamic acid, which is then converted into hippuric acid. In addition to cinnamaldehyde, other derivatives of allylbenzene may be present in small quantity, such as eugenol, safrol, and anethol, which are all closely related to cinnamaldehyde, and show similar reactions to lignine (*Chem. Zeit.*, 1889, 13, 659). Judging both from the strength of the phenol reactions and the amount of hippuric acid in the urine of graminivorous animals, cinnamaldehyde probably occurs in wood fiber to a larger extent than any of the other aromatic compounds.

The aromatic derivatives contained in wood fiber are all derived from the same hydrocarbon, allylbenzene, which has the formula $C_6H_5-CH=CH-CH_3$. They are given, with their constitutional formulæ, in the following list:

Cinnamaldehyde....... $C_6H_5-CH=CH-COH$
Eugenol............. $C_6H_3\,(OH)\,(OCH_3)\,(C_3H_5)$
Safrol.................. $C_6H_3\,(O_2CH_2)\,(C_3H_5)$
Anethol................. $C_6H_4\,(OCH_3)\,(C_3H_5)$
Coniferyl alcohol.. $C_6H_3\,(OH)\,(OCH_3)\,(C_3H_4OH)$
Vanillin (an oxidation product of
eugenol)........... $C_6H_3\,(OH)\,(OCH_3)\,(CHO)$

The next question which arises is in what form annamaldehyde and the other aromatic compounds are present in lignine. Cinnamaldehyde is not there in the free state, because the proper solvents do not extract it from wood. Only oil of turpentine, out of a number of solvents, was found to remove something from wood which gave a reaction with phloroglucol and other phenols. In order to answer the question referred to, I sought to ascertain whether cinnamaldehyde occurs in the free state in cinnamon, and found that it does not. Genuine oil of cinnamon is obtained, as is well known, by distilling the stem of cinnamomum Ceyl. B., after the corky bark has been removed, with salt water. Alcohol and ethereal extracts of cinnamon, or similar extracts made with oil of turpentine and other liquid hydrocarbons, however, do not give the reactions of oil of cinnamon. In the same way the oils of cloves, pimento, and sassafras do not exist ready formed in the plants, for these plants do not show their reactions. These volatile oils are, therefore, first formed during the actual distillation with salt water. Cinnamaldehyde probably occurs in cinnamon, chemically combined with a hydrocarbon and perhaps with other fixed substances; eugenol is combined in cloves with a sesquiterpene, $C_{15}H_{24}$, etc. The plants from which ethereal oils are prepared probably contain compounds which behave like glucosides; by distillation with water, salts, alkalies, or acids, and by the action of ferments, they are split up into their components, which are usually terpenes, camphors, resins, aromatic compounds, and other substances.

It is not unlikely that similar relations prevail in lignine; here, too, aromatic compounds, such as cinnamaldehyde, eugenol, vanillin, etc., are combined with terpenes, resins, camphors, and gum, and perhaps also with cellulose. These compounds are decomposed into their constituents by boiling with acids and alkalies, especially under pressure, in the same manner as the glucosides; such a decomposition takes place to a certain extent when wood is simply boiled with water.

I classify lignine from a consideration of its composition along with the so-called gum resins. This class of substances comprises such as are made up of gums, resins, and ethereal oils, all of which occur in lignine. In this particular substance, however, only a very small proportion of resin is present, whereas the gummy constituents are well represented. I have been able to obtain almost the same color reactions with phloroglucol and aniline sulphate from some commercial balsams and resins as from lignine; among these are old Tolu balsam, which has become solid, benzoin resin, and in less degree Peru balsam.

The chief constituent of the incrusting substance of wood is of a gummy nature, and the separation of this matter becomes of great importance in the production of wood cellulose.

The gummy substances themselves show a close analogy with arabin, and are found in the sulphite process in the waste liquors in the form of calcium salts of the gum acid, or, in the soda process, as sodium salts, although in this case they have been altered to a certain extent. When the spent sulphite liquor from pine wood is carefully evaporated, a brittle, transparent, yellowish brown, resin-like mass of these calcium salts is obtained.

This mass has practically the same properties as gum arabic. It is readily soluble in water, but insoluble in alcohol, etc. A concentrated solution in water gives, on boiling with phenol solution and a large quantity of concentrated hydrochloric acid, or better when concentrated sulphuric acid is added, similar color reactions to the carbohydrates described by me (*Chem. Zeit.*, 1887, 11, 2). An alcoholic solution of phloroglucol in particular acts in a similar manner as with gum arabic on continued boiling in the presence of hydrochloric acid.

These gum acids, then, which occur in wood, are soluble in water and, like arabic acid, give salts with lime and other oxides, which are readily soluble in water and are precipitated by alcohol. Moreover, these substances have, in common with arabin, the property of being tolerably strong acids, so that they decompose carbonates, sulphites, and sulphides, especially when heated under pressure, a fact which is of great importance. Carbonic acid does not precipitate the lime from the solution of the resinous mass described above.

When wood, therefore, is boiled with caustic soda under pressure, the lignine is first of all decomposed into its constituents, the gummy substances undergo partial alteration, and are dissolved, along with the resins and phenols, the volatile substances, such as the terpenes, etc., volatilize; the aldehydes, such as cinnamaldehyde and vanillin, which readily condense, polymerize to substances which either dissolve in the caustic soda or, if they are volatile, escape. Coniferin is split up, and both its components brought into solution.

It is well known that sulphurous acid very readily exerts a decomposing or polymerizing action on many groups of organic compounds. In the sulphite process, the free sulphurous acid first of all decomposes the lignine; the gum acids thus set free act under a somewhat higher pressure upon the calcium sulphite in solution, forming calcium salts, which remain in solution, and free sulphurous acid, which escapes.

These facts explain the chief points in the sulphite process. The terpenes and aldehydes, which very readily condense under the action of sulphurous acid, are to a large extent volatilized along with the sulphurous acid in the form of polymeric compounds, and are accompanied by the other volatile constituents of the wood substance, while the non-volatile bodies, such as the resins, remain behind, chiefly in the form of calcium salts. The sulphite process will succeed best when just sufficient sulphite of lime is employed to neutralize the gum acids. If an excess be taken, there is a danger of sulphite of lime adhering to the fiber.

If the temperature were to be raised too high, there might be a danger of a reduction of the gum acids by the sulphurous acid, resulting in the formation of organic acids whose calcium salts are insoluble in water, or which are unable to decompose sulphite of lime.—*Chem. Tr. Jour.*

A REPORT on electric lighting of trains in Germany leads to the conclusion that such lighting must be independent of the locomotive, and that it must be on the accumulator system.

FILTERED WATER AT NANTES.

THE question of supplying cities with drinking water is, on every side, invested with difficulties that are ever increasing along with the increase in density of their population. The best way to solve this problem evidently consists in curbing sources at a distance and leading water from them into the city reservoirs; but this method, which is very costly, is more and more exciting the protest of the owners of the sources and of the inhabitants of the banks of the water courses fed by such sources before being curbed. They make cities pay very dearly for the precious liquid, while at the same time, as was recently seen at the time of the curbing of the sources of the Avre and the Vigne for Paris, they see the hydraulic power that was at their disposal replaced by steam power, which is very burdensome. Our engineers and our hygienists have with just reason asked themselves if it would not be possible to introduce practically into consumption the water of rivers upon which masses of people are invariably congregated. It was always with such water that cities were supplied at first; but all abandoned it in succession as soon as the massing of the population polluted it by the throwing into it of all sorts of solid and liquid refuse.

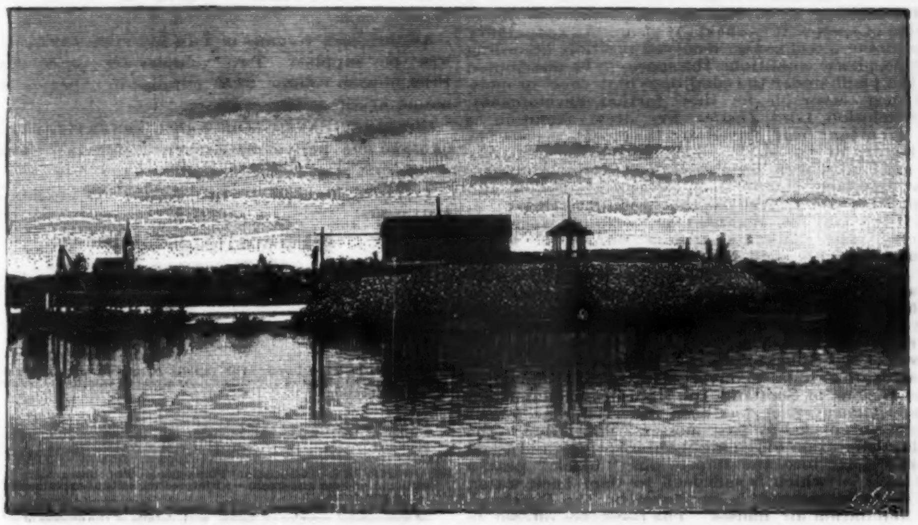


FIG. 1.—ISLE BEAULIEU, NEAR NANTES, SITE OF THE LEFORT WELL.

Is it not possible, however, to draw such water above the cities before it has been polluted, and to filter it properly so as to render it as potable as the pure water derived from springs? This question was very clearly put to the congress on the utilization of river waters at the exposition of 1889, and gave rise to a warm controversy. To a portion of our hygienists river water seems to be forever condemned and incapable of entering into consumption; while to others, equal in number, and among whom we place ourselves, river water, well filtered, is just as good as spring water. A source of water, as pure as one may wish it, may, in fact, be polluted at a distance by the incorporation of germs, and will prove so much the more dangerous, perhaps, in proportion as one suspects it the least. The river water derived from the great natural filter formed of the earth with its varied purifying strata has in its favor dilution in an enormous volume. On collecting it, as we have said, before it has been polluted by the crowded centers of population on the banks, and on filtering it in a rational manner, we ought to be able to drink it without danger.

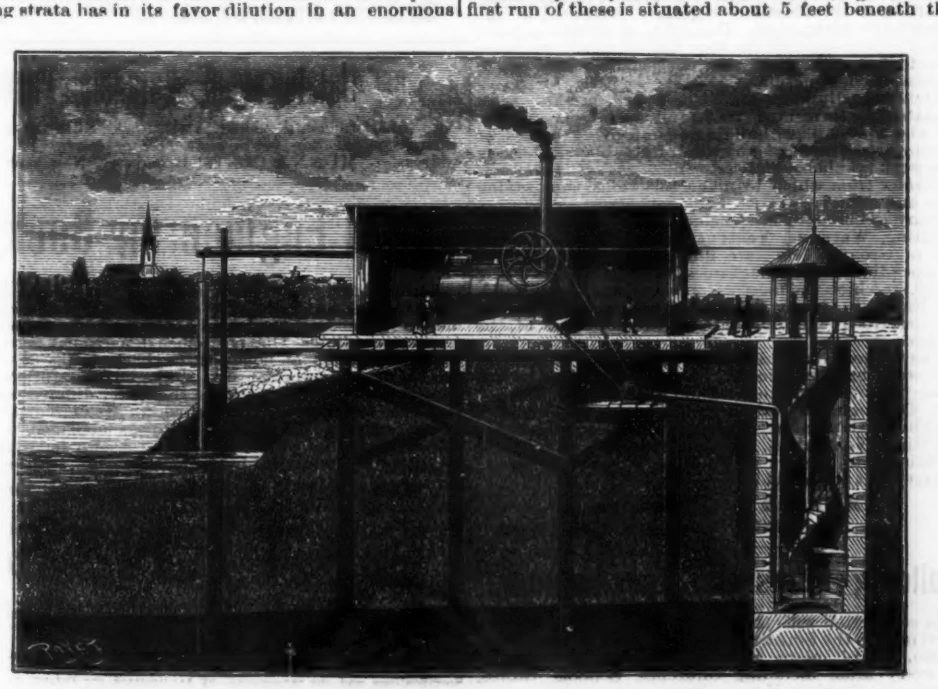


FIG. 2.—VERTICAL SECTION OF THE WELL AND PUMPING ENGINE.

This is precisely the theory that has just been emitted by Mr. Lefort, the learned engineer in chief of bridges and roadways of the city of Nantes. He has pursued the realization of it with a patience and conviction that has been crowned with success. Confining himself to his role of engineer for the practical realization of the problem, Mr. Lefort, as regards the matter of hygiene, respectfully placed himself under the control of our most distinguished chemists and bacteriologists—Messrs. Audouard, Debray, Gautrelet, Miquel, Vaillard and Bureau, as well as Prof. Jouon, who presented the new system to the Society of Public Medicine and Professional Hygiene. The results obtained by these various scientists agree, and we may conclude therefrom that the river water coming from a Lefort well can be used without hesitation for public consumption.

We shall permit ourselves to be very distinct in this affirmation, and the more so in that the honorable engineer, whose splendid work we briefly appreciate, has not cared to take out a patent, and has desired merely to be useful to humanity, with that breadth of view and that disinterestedness that our French scientists bring to problems of this kind. The Lefort system is as follows: After trying with scientific precision the process of the great artificial filters, which filter very little and very badly, Mr. Lefort took as a filter an artificial island constructed in the Loire on the site of the Isle Beaulieu, 8,660 feet above the city and the zone of pollution of the water that it empties into the river. Figs. 1 and 2 show the arrangement of it. The well from which the water is drawn is situated nearly in the center of the island, the mass of which, properly arranged, serves as a filtering material.

The whole shore at this place is formed of beautiful sand of medium sized grain, and of variable thickness, limited by a thick stratum of compact mud, which extends to about 7½ feet below the lowest water.

The filtering well is established upon an iron plate caisson that supports its masonry. It is surrounded by an embankment of pure sand, covered by a packing of stone 16 inches in thickness, and by a terminal granitic rock wall. Its internal diameter is 6½ feet. Its masonry is of mortar of hydraulic lime and cement, with an internal and external coat of cement.

The filtered water enters the well through 66 inlets, which may be opened or closed at will (Fig. 3). The first run of these is situated about 5 feet beneath the lowest water, in the vicinity of the Isle of Bleaulieu. Each inlet is formed of a block of cement 20 inches in length and $\frac{16\text{ in.}}{16\text{ in.}}$ hollow in the interior. In half of the thickness, the hollow has the form of a truncated cone having an internal diameter of 8 inches and an external one of 12 inches. The cavity is filled with small broken stones, which are held in place by a metallic grille. In the second half of the thickness, the cavity is cylindrical in form, and 4 inches in diameter, and this opening can be closed either with wooden plugs or with an arrangement of cocks that facilitate the entrance of the water at the various inlets, and the closing of the latter. The total depth from the top of the curb to the bottom of the well is 24 feet. The well is sunk 15 feet below the shore. A spiral stairway permits of one's descending and of opening at will one or the other row of inlets. Such is a brief description of the installation, which has been elaborated with the most scrupulous care in all its details.

The experiments on the output, made continuously for more than a month, day and night, permit of the conclusion that a well of this kind, 6½ feet in diameter, containing 10 inlets per row, spaced 20 inches apart in a vertical direction, is capable of giving, with three rows of inlets only, 528,000 gallons of potable water in 24 hours, say 158,400,000 gallons in a year of 300 days, on condition that the plane of the water of the river remains at least at 3 feet above the upper (third) row, that is to say, that the lowest row is at least 6 feet below the lowest water.

In a total estimate for twelve wells proposed to the city of Nantes by Mr. Lefort, for a supply of 8,000,000 gallons, or 250 quarts of water per inhabitant per day, the quantity demanded by hygiene, the net cost of each well is put at $7,000.

As regards the wholesomeness of the water thus obtained, we shall borrow a few figures from the excellent reports on this subject presented by Prof. Jouon to the Society of Public Medicine and Professional Hygiene.

The water drawn from the wells is limped and fresh—a primordial condition of quality for a potable water. The substances in suspension in the river are totally averted by the filter. The number of bacteria per cubic inch, which is 384,000 in water taken directly from the Loire, falls to about 2,400 in the water from the well. These figures result from analyses made by Mr. Miquel at the Montsouris Observatory and by Mr. Vaillard at the Val-de-Grace Laboratory. Now

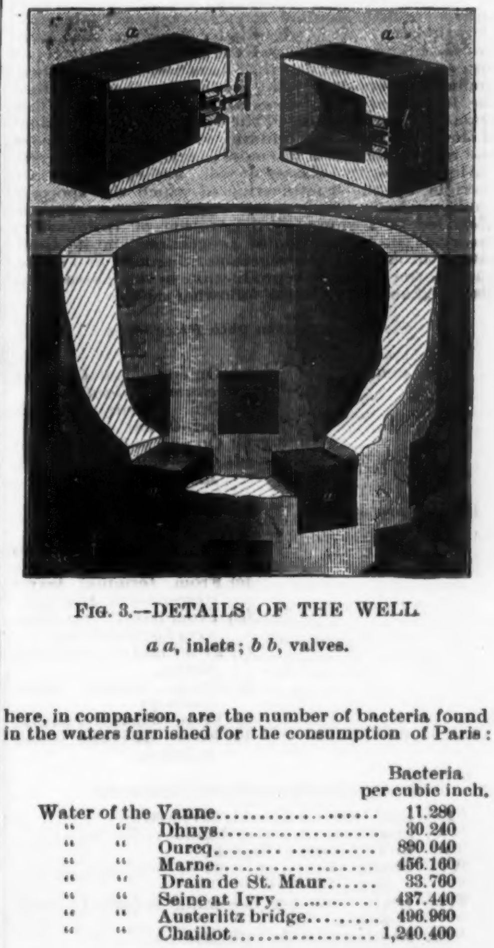


FIG. 3.—DETAILS OF THE WELL.

a a, inlets; *b b*, valves.

here, in comparison, are the number of bacteria found in the waters furnished for the consumption of Paris:

	Bacteria per cubic inch.
Water of the Vanne	11.280
" " Dhuys	30.240
" " Ourcq	890.040
" " Marne	456.160
" " Drain de St. Maur	33.760
" " Seine at Ivry	437.440
" " Austerlitz bridge	496.960
" " Chaillot	1,240.400

These are the general bacteriological averages of the waters of Paris during the years 1887, 1888 and 1889. They are unpleasantly suggestive.

Is it to be said that Mr. Lefort's excellent system is to be immediately substituted for all others, and that in a near future spring water will no long enter into public consumption? We shall not go as far as that; but, convinced that, in an intelligent civilization, water in profusion is the basis of public health and salubrity, we believe that the Lefort wells will furnish a powerful and useful aid in the supply of our large cities.

It is by the application of these progressive processes that we shall, in a large measure, succeed in causing to disappear from our crowded centers a large number of scourges, especially the terrible typhoid fever, which carries off our generations in the flower of life. We well know the results obtained by our eminent Minister of War, Mr. Freycinet, in seeing to the distribution of potable water in our barracks. Again, such water must be obtained with certainty, economy, and in abundance. The process recommended by Mr. Lefort appears to us to be one of the solutions of the problem. We shall be greatly pleased to see some specimens of it installed in our large cities, without forgetting our intrenched camp of Paris. This process, which the precision of laboratory analyses encourages and confirms, has, in fact, in opposition to it, nothing but arguments borrowed in great part from routine and prejudices.—*La Nature.*

MOSSES.

OWING to the unavoidable absence of Lord Rayleigh, the first Friday evening lecture of the session was delivered at the Royal Institution on January 23, by the Right Hon. Sir Edward Fry, Lord Justice, the subject of his discourse being "British Mosses." Lord Justice Fry said that he appeared only in the character of a student, who was anxious to introduce a subject in which he found so great delight to the consideration of others.

The right hon. speaker proceeded to point out the position occupied by the mosses in the vegetable kingdom as the highest developed form of the cellular cryptogams, and alluded to their tendency to fibro-vascular structure, and the chasm existing between mosses and higher cryptogams. The older classification of the Muscinæ into the groups *Musci*, *Sphagnaceæ* and *Hepaticeæ*, and of the group *Musci* into the subgroups *Pleurocarpeæ*, *Acrocarpeæ* and *Anomoleæ*, was adopted, and of these the *Acrocarpeæ*, which bear an urn (sporogonium) at the end of the axis of growth, and the *Pleurocarpeæ*, in which the capsule is developed laterally, were especially recommended for study. The number of British species amounts, said the lecturer, according to the latest calculations, to eight or nine hundred, and the date of the native moss flora has been referred to the tertiary glacial period.

Two very ancient collections occur in Scotland; the more important contains eleven species, of which at least ten have been identified with existing forms. It was discovered in the interglacial beds of Renfrewshire, so that accepting Wallace's chronology, these specimens must be from one hundred to one hundred and fifty thousand years old. The second collection, consisting of four species of *Hypnum* still occurring in the valley of the Clyde, was discovered not far from Glasgow, and is of equal antiquity. In both collections the predominant genus is *Hypnum*, to which the long, straggly mosses of the woods and fields in the present day belong.

In France species of *Polytrichum* have been found in the coal formation, but from the absence of vascular bundles, and consequently the want of tissue capable of offering strong resistance to the action of water, mosses are little adapted for preservation in the state of fossilization. It is noteworthy, however, that, as in the vascular cryptogam, it is the most highly developed forms of the present day that have been found in these prehistoric deposits. Lord Justice Fry then described the life history of a moss, and illustrated with diagrams the germination of the spore, the development of the protonema, the budding or division into leaves and roots which form the moss plant, and the differentiation of the two classes of cells, archegonia and antheridia, by the fructification of which the sporogonium producing fresh spores results. These explanations led to a summary delineation of Hofmeister's theory of the alternation of generations and its application throughout the vegetable kingdom, and subsequently the modes of reproduction in the mosses were discussed according to the following scheme:

A. *Reproduction with Protonema.*

I. By spores.

II. By gemmæ.
- (*a*) On end of leaf (*Orthotrichum phyllanthum*).
- (*b*) On midrib (*Tortula papillosa*).
- (*c*) On axis of leaf (*Bryum*).
- (*d*) On balls (*Aulacomnium*.)
- (*e*) In cups (*Tetraphis*).

III. By protonema.
- (*a*) From rhizoids (*Phascum*).
- (*b*) From aerial rhizoids (*Dicranum undulatum*).
- (*c*) From terminal leaves (*Oncophorus glaucus*).
- (*d*) From base of leaf (*Funaria hydrometrica*).
- (*e*) From midrib (*Orthotrichum*).
- (*f*) From margin (*Buxbaumia*).
- (*g*) From stems (*Dicranum*).
- (*h*) From calyptra (*Conomitrium*).

B. *Reproduction without Protonema.*

IV. Leaf buds on rhizoids (*Grimmia*).
V. Leaf buds on aerial rhizoids (*Dicranum*).
VI. Bulbs on stem (*Bryum*).
VII. Young plants at ends of branches (*Sphagnum*).
VIII. Leafy branches becoming detached (*Cinclidotus*).
IX. Rooting of main axis (*Mnium*).

In view of these numerous methods of reproduction of which the mosses are in possession, the lecturer somewhat severely criticised Dr. Weissman's new theory of division of cell plasma. The latter investigator distinguishes two kinds of cells, or rather two kinds of plasma in living cells, of which the one, the germ plasma, is endowed with natural immortality, since it is capable of being transmitted from generation to generation, while the second is mortal or somatic. Lord Justice Fry remarked that the readiness with which every part of a moss reproduces itself would either suggest that there is no such division of the plasma or else that the two hypothetical modifications are very intimately mixed throughout the plant, and the tone in which the remark was made betrayed the bias of the right hon. speaker for the first alternative. A few comparisons were then drawn with respect to vegetable and animal embryology, and it was pointed out that in both kingdoms evidence of a process of evolution could be gathered.

Thus in the early stages of a moss the protonema indicated descent from an alga, and a change in the mature condition was analogous to that from the gilled tadpole to the batrychial frog. Moreover, in the reproductive methods employed by the mosses there is an evident attempt to escape the necessity of "recapitulation" and a tendency to substitute a shorter process for the ancestral method, "a kind of short-circuiting," as the lecturer expressed it, which makes itself visible in asexual reproduction. Returning from these theoretical considerations, Lord Justice Fry next showed a magnificent large model of German manufacture of a moss capsule, the length or height being from two to three feet.

The veil or calyptra, the remains of the archegone, was represented by a thin translucent covering, which lifted off and brought the sporogonium to view. Upon removal of the cap, the teeth of the peristome were disclosed, and finally by displacement of one side, the arrangement of the spores within the capsule demonstrated. The extraordinary variety and beauty of the shape and configuration of the peristome in different species, the simplest form of four teeth occurring in *Tetraphis*, was illustrated by the lecturer with the aid of numerous diagrams. He also pointed out that, besides the function attributed to the preistome by a field botanist as an adjunct for the facilitation of definition of species, it enabled, by means of its capability of assuming a reflexed or recurved position, according to atmospheric conditions, the spores to be distributed by the plant under the conditions of dryness or moisture most favorable for their further development. In conclusion, Lord Justice Fry drew attention to the important role played by the "peat mosses" in the history of the world. The morphological habits and anatomical structure of various species of *Sphagnum* peculiarly adapt them for the absorption and retention of the largest possible quantity of water, so that they may be regarded as veritable vegetable sponges. The shape and arrangement of the leaves upon the stem is such as to allow full play to capillary attraction, while the large cells surrounding the denser tissue of both leaves and stems act simply as pitchers for the storage of water. This property of the peat mosses guards the lower lying land from damage by freshets in times of heavy rain, while by the upward growth of the Sphagnaceæ and subsequent decay the morasses are gradually converted into solid ground. In some regions of Scotland, the Hebrides, Holland and Ireland, however, it has been observed that forests have been replaced by peat mosses. This is due to the gradual alteration of the highly absorptive "red" and "white" peat into the impervious "black" peat, a thin layer of which is sufficient to dam back water, and on this account is employed by the Dutch as the foundation for houses. The resistance offered to drainage by this modification of peat destroys the conditions under which the growth of forests is possible.

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